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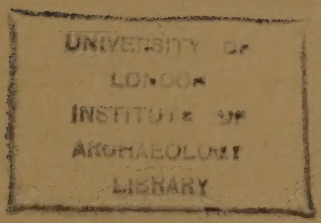

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Archaeology is
about and
buried.

CONTENTS

Greek Colonization and the Early Iron Age East of the Volga

A Guide to the Recent Literature on the Subject[1]

by T. SULIMIRSKI

The present, fifth, report on recent archaeological literature of the U.S.S.R. is devoted, as announced in the preceding report (*Bulletin* 10, p. 99) to the Greek colonization of the northern coast of the Black Sea, and to the eastern part of Eastern Europe east of the Volga and the Kama during the Early Iron Age; some items either missed in the previous reports, or published after the completion of *Bulletin* No. 10 have been added. The literature published approximately between 1958 and 1971 has been taken into account, but the section devoted to the Greek colonies does not keep strictly to this chronological limit. As previously, only books, pamphlets and periodicals accessible in the main archaeological libraries in London were considered; they have been handled in about the same way as formerly.

Publications of a general character

Publications of this type relating to the Early Iron Age, including the Scythian Age, have been considered in my former reports (*Bulletins* 8/9 and 10). Newly published is the fine book *Skify* (*The Scythians*, Moscow 1971, 168 pages, 28 half-tone

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*In this article the following are the chief abbreviations used:

AF:	*Issledovaniya po Arkheologii SSSR* (Artamonov Festschrift), Leningrad 1961.
AIU:	*Arkheologicheskie Issledovaniya na Ukraine* 1965–1966, Kiev 1967.
AK:	*Arkheologiya*, Kiev (in Ukrainian, mostly with a short summary in Russian).
AO:	*Arkheologicheskiye Otkritiya*, Moscow.
AP:	*Arkheologichni Pamyatky URSR*, Kiev (in Ukrainian, mostly with a short summary in Russian).
ASE:	*Arkheologicheskii Sbornik*, Hermitage, Leningrad.
IADK:	*Istoriya i Arkheologiya Drevnego Kryma*, Kiev 1957.
KSAMO:	*Kratkie Soobshcheniya Arkheologicheskogo Muzeya*, Odessa.
KSIAK:	*Kratkie Soobshcheniya Instituta Arkheologii*, Kiev.
KSIAM:	*Kratkie Soobshcheniya Instituta Arkheologii AN SSSR*, Moscow.
KSIIMK:	*Kratkie Soobshcheniya Instituta Materialnoy Kultury*, Moscow.
MASP:	*Materialy po Arkheologii Severnogo Prichernomorya*, Odessa.
MIA:	*Materialy i Issledovaniya po Arkheologii SSSR*, Moscow–Leningrad.
SA:	*Sovetskaya Arkheologiya*, Moscow.
SVOD:	*Svod Arkheologicheskikh Istochnikov. Arkheologiya SSSR*, Moscow–Leningrad.
VDI:	*Vestnik Drevney Istorii*, Moscow–Leningrad.
ZOAO:	*Zapiski Odesskogo Arkheologicheskogo Obshchestva*, Odessa.

1. *Bulletins* No. 6 for 1966; No. 7 for 1968; Nos. 8–9 for 1969–70; No. 10 for 1971 of the Institute of Archaeology (pp. 94–129; 43–83; 117–150; and 99–140, respectively).

plates, several illustrations in the text) by B. N. Grakov. This is a rewritten but to some extent similar and popular edition in Russian of a paperback by the same author published under the same title in Ukrainian in 1947 in Kiev.

A recent publication is a fine manual in three volumes, a collective work, the chief editor of which is Professor S. N. Bibikov, entitled *Arkheologiya Ukrainskoy RSR* (*Archaeology of the Ukrainian SSR*, written in Ukrainian), two volumes of which are available in London: vol. I (Kiev 1971, 452 pages) deals with the Palaeolothic, Neolithic and the Bronze Age; written by 22 authors. Vol. II (Kiev 1971, 504 pages, written by 10 authors) is devoted to the 'Scytho-Sarmatian Age' and to the Greek colonies on the North Pontic coast. Both volumes are profusely illustrated, with a number of coloured plates, and contain several maps.

Another recent publication (paperback) is *Problemy Skifskoy Arkheologii* (*Problems of Scythian Archaeology*, *MIA* 177, 1971, 220 pages, profusely illustrated; editors P. D. Liberov and V. I. Gulyaev). It contains articles by 29 authors who discuss the origin of the Scythians, the placing of the peoples mentioned by Herodotus, the relationship between the tribes of the Scythian culture who lived in the steppe and those in the forest steppe zone, Scythian art, etc. A special section (pp. 127–164) is devoted to the Crimea.

A few larger articles, published recently, discuss wider themes relating to the Scythians and their culture. One of these, by M. S. Sinitsyn (*MASP* IV, 1962, pp. 33–60) brings a general review of the various types of burials and of the changes in the burial rites during the Scytho–Sarmatian Age and in the area between the rivers Dniester and the Southern Bug. M. Viazmitina (*SA* 1969 (4), pp. 62–77) tries to explain the causes which led to the development of fundamental differences between the Early (6th–5th centuries B.C.) and Late Scythian culture (4th–3rd centuries B.C.). E. A. Symonovich (*ZOAO* I, 1960, pp. 154–162) discusses the ethnic identity of the peoples who lived in the lower Dnieper steppes at the turn of the Christian era.

A different theme was dealt with by V. A. Ilinskaya (*SA* 1971 (2), pp. 64–85), who has already published a series of articles on several decorative motifs popular in Scythian art, this being a special study of the carnivore felines. This motif appeared in the early stage of the Scythian art, and was evidently taken over from the ancient Oriental art. The same author (*AK* 1971 (4), pp. 73–79) discusses a series of Scythian gold ornaments of the Archaic period (6th century B.C.) which she connects with the sun symbols and with the idea of fertility. D. S. Rayevskii (*SA* 1970 (3), pp. 90–101) deliberates on the meaning of the scenes depicted on the toreutic of the Late Scythian period, on silver vases from barrow 3 of the Chastye group at Voronezh and from Kul-Oba in particular. He is of the opinion that they are connected with the legends on the origin of the Scythians and represent the ideology of the Late Scythian kingdom, and that of Ateas of the subsequent period. The book *Iz Tsarstva Ateia v Neapol Skifskii* (*On the Kingdom of Ateas in the Scythian Neapolis*, Moscow 1968, 168 pages) by A. A. Shtambok was not available in London. It was reviewed by O. D. Dashevskaya (*SA* 1971 (3), pp. 296–298).

M. V. Gorelik (*SA* 1971 (3), pp. 236–245) tries to reconstruct the Scythian scale armour from an engraved drawing on a gold plaque found in the Geremesov barrow grave of the 4th century B.C., situated in the steppe on the right bank of the lower Dnieper. In the rather popular account *Khudozhestvennye Sokrovishcha Drevney Moldavii* (*Art Treasures of Ancient Moldavia*, Kishinev 1967, 112 pages including 52 half-tone illustrations) by A. E. Rikman, examples of ancient Romanian and Bessarabian art from the Palaeolithic to the XVIIth century have been classified and commented upon. Of interest are two articles by L. A. Elnitskii, one of which (*SA* 1960 (4), pp. 46–56), missing from my previous report, is devoted to ancient Scythian cults and deities quoted by Herodotus and to their origin. In the second one (*SA* 1970 (2), pp. 64–74), the author discusses the cultural and historical aspects of ancient Scythian legends recorded by Herodotus. On the other hand A. I. Meliukova (*KSIAM* 105, 1965, pp. 32–41) quotes Scythian objects found in Romania and Scythian elements in the culture of the Getae in the country west of the Pruth, of Bessarabia. According to her these elements appeared there in the 8th century B.C., at the time at which she dates the beginning of the Scythian influence.

Thracian brooches in ancient Thracia of the 7th to 5th centuries B.C. have been studied by T. D. Zlatkovskaya and D. B. Shelov (*SA* 1971 (4), pp. 50–70). Their development has been discussed and diffusion of their various types in the country south of the Danube shown in a series of maps. The authors conclude that the main centre of their production was in the Rodope Mountains, and that during the time of the early Odrysian Kingdom a marked uniformity of the brooches within the whole area of the Kingdom has been observed.

The results of their new study of working of iron in ancient Scythia in the 7th to 5th centuries B.C. have been published by B. A. Shramko, L. D. Fomin and L. A. Solntsev (*SA* 1971 (4), pp. 140–153). They imply that Scythian ironsmiths were very well acquainted with the technique of working iron and of manufacturing iron weapons, swords in particular.

Three reports by V. I. Tsalkin of the results of the study of the osseous material from a large number of settlements and graves in many parts of Eastern Europe, dating from various periods including the Early Iron Age, have been mentioned in *Bulletin* 10 (pp. 105f.). However, an omission has been the earliest of these, *Fauna iz Raskopok Arkheologicheskikh Pamyatnikov Srednego Povolzhia* (*Fauna from Archaeological Excavation of Relics in the Region on the Middle Volga*, *MIA* 61, 1958, pp. 221–281) which brings data relating to 29 settlements and barrow graves in that area, of the time from the Bronze Age to the Early Mediaeval period; the changes which took place in the set of domesticated animals during this period in that area are discussed as are the differences in this respect between the regions of the forest and the steppe zones. His more recent study is *Drevneyshie Domashnye Zhivotnye Vostochnoy Evropy* (*The Earliest Domesticated Animals of Eastern Europe*, *MIA* 161, 1970, 280 pages, a small paperback), and another one of this type is *Rannee Zemledelie i Zhivotnovodstvo v Lesnoy Polosie Vostochnoy Evropy* (*Agriculture and Stock-rearing in the Forest Zone*

of Eastern Europe, MIA 174, 1971, 168 pages, 82 illustrations including several maps). The book (paperback) deals with the period from the second millennium B.C. to the mid-first millennium A.D.

Addenda

Recently published have been the results of investigation of a series of settlements and burials of the Scythian Age in various parts of ancient Scythia, including several richly furnished burials of Scythian warriors, evidently members of the local aristocracy. But the most important are reports on the discoveries of a number of extremely richly endowed Scythian princely, or royal, burials in the Ukraine of the Late Scythian period, the 4th and 3rd centuries B.C.

One of these, presumably a royal burial, was a barrow grave called Gaimanova Mogila, reported by V. I. Bidzilya (*AK* 1971 (1), pp. 44–56, 11 figures; also in *Illustrated London News* of 18th of April 1970, pp. 24f., figs. 1–7), situated at Balky on the southern bank of the upper reach of the artificial water reservoir called the Kakhovka Lake, at the southern extremity of the Dnieper bend south of Zaporozhe. It was 70 m. in diameter, 8 m. high and belonged to one of over 20 groups of barrow graves scattered in that region. Each group possessed a few large mounds. Twenty-three barrow graves were recently excavated in that region, all being of the Late Scythian period except for four mounds which were of the Bronze Age. The extremely richly furnished royal grave of the Gaimanova Mogila was in a deep 'catacomb', with a large burial chamber and niches. Two men and their wives were buried in the main chamber, and they were accompanied by six attendants, at least one woman among them, three men being well armed. The burial was partly looted, but the cache in which rhytons and other silver vases were hidden escaped discovery by the looters. A partly gold-plated silver vase, decorated with scenes from the Scythian high life ranks among the best examples of the Late Scythian art. The burial has been dated at the beginning of the second half of the 4th century B.C., which means around 350–340 B.C.

Several barrow graves of the Late Scythian period (4th–3rd centuries B.C.) and a few of the very end of the 5th century B.C. were excavated at Arkhangelskaya Sloboda west of Nikopol, near the newly constituted town Ordzhonikidze, north of the Dnieper, as reported briefly by A. M. Leskov (*AO* 1969, pp. 232–233). Several mounds were very large, and most burials in these had been looted. One of these was the princely or royal burial in barrow grave 1, 65 m. in diameter, 6·5 m. high, which had a large shaft in the centre, 4·5 by 3·5 m. in area, 4·5 m. deep and four 'catacombs' dug out in its corners. Only the iron scales of armour and of a battle belt, bronze arrow-heads and sherds of amphorae were found; all caches had been ransacked, but the horse burial near the main shaft was intact; horse harness, head ornament and 12 decorative silver plaques and other ornaments were found there, several decorated in the Scythian animal style. The barrow-grave was at a distance of only 6 km. from the famous Chertomlyk barrow grave. Barrow grave 5 was found nearly unlooted. In its shaft, covered with planks, a Scythian prince was buried in a wooden coffin, head to west.

Three quivers with over 450 arrows, various iron articles and gold ornaments were found there. Among the latter was a gold neck-ring (310 grams), its terminals decorated in filigree and coloured enamel, a splendid work of a highly skilled goldsmith. In a hide-out stood a wooden vase covered with gold sheet decorated in the zoomorphic style. It seems that the two richly furnished barrow graves mentioned in the western journals had belonged to the same group of princely burials investigated in this region. One of these 'near the city of Dnepropetrovsk' (*Daily Telegraph*, London, of 31st May 1971) contained the burial of a queen who 'bore a golden crown and wore a necklet bearing figures of a strange animal and lions'. A sarcophagus nearby 'lined with alabaster, contained the remains of a boy, about two or three years of age', whose 'body was also richly attired'. The other one was one of 'the huge mounds of earth outside the town of Ordzhonikidze called 'Tovsta Mohyla' ('Thick-barrow'). It was 8.6 m high, about 70 m in diameter. Its central royal tomb in a 'catacomb' was looted, and the skeleton of the prince ruined. In spite of that, over 600 gold objects and ornaments were collected. The equipment of the prince consisted of weapons (quivers with bronze and bone arrow-heads, iron lance-heads, an iron sword in a gold-covered wooden sheath, iron scale-armour, bronze greaves, etc.), a large number of decorated ornaments including the most spectacular objects, a magnificent gold pectoral ornament; several small silver vessels, Greek vessels and amphorae etc. Nearby seven horses were buried, some with mainly silver, richly decorated, parts of bridoons. Two skeletons, of a groom near the horses, and of a servant in the dromos were also uncovered. Under the south-western part of the mound was another, untouched, richly furnished 'catacomb' grave, of a princess buried with her two/three year old child, accompanied by two maids and a fully armed warrior. A large number of small decorated gold plaques were found which originally were sewn on the headdress, the whole dress, and on the cover of the bed. There were many beads of paste, silver and gold, bracelets, gold neckring, bronze mirror, etc. The type of the burials, the style of the furniture and its decoration, point to the mid-fourth century B.C., and link the graves with those of the Chertomlyk barrow that lie in the vicinity, but have been considered of a little later date. A brief description of the mound appeared in *Time* (January 1972, p. 44), and in the *Illustrated London News* (of July, 1972, No. 2371, p. 51). Recently a report on excavation was published by B. M. Mozolevskii (*AK* 1972(5), pp. 72–82), and another one, in German, relating to all excavations above, was published by R. Rolle (*Prähistorische Zft*, vol. 47/1, 1972).

In the steppe 3 km. west of Kuibyshev in the district of Nikopol north of the Dnieper two groups of barrow graves were investigated in a site called Orlova Mogila, two of which were 7 and 5 m. high. In group I, three barrow graves were of the Bronze Age, but most graves were of the Late Scythian Age, of the 4th century B.C. Several mounds in both groups contained 'catacombs' with two entrance shafts; all such chambers had two burials inside. The majority of graves investigated were looted, and usually only weapons—iron lance-heads, iron and bronze arrow-heads, Scythian battle-belts, but occasionally also bronze cauldrons, iron knives with bone hilts, and

some personal ornaments, especially glass beads—were found there. This was also the lot of the originally richly furnished princely barrow grave 3. It was 5 m. high, its entrance-shaft 7 m. deep, the burial chamber 3 m. square, with a dromos. Only a number of iron scales of the armour, arrow-heads, a few small gold plaques, pieces of rusted iron etc. were found, and sherds of a Heraclean amphora showed the date of this double burial, the 4th century B.C. (V. S. Bochkarev and others, *AO* 1969, pp. 237–239).

A few barrow graves were investigated further south, in the steppe north of the lower Dnieper. Thus in a small barrow situated near Berislav, between Nikolaevka and Kamenka, a broken Scythian limestone stela was found carved in relief as a crude figure of a Scythian warrior, only the head of which, dressed in a helmet, survived, as reported by E. A. Symonovich (*AO* 1969, p. 246). The same author (in *Drevnosti Vostochnoy Evropy*, *MIA* 169, 1969, pp. 230–232) describes two bronze cauldrons of the 4th century B.C., one found in a barrow grave near Kamenka near Kakhivka, damaged and repaired in antiquity, the other found in the small river Kozak near Berislav. O. G. Shaposhnikova (*SA* 1970 (3), pp. 208–212) describes another richly furnished burial of a Scythian warrior of the late 5th century B.C. at Novaya Rozanovka on the Ingul, north of Nikolaev (see P. P. Tolochko, *AO* 1967, p. 187, reported in *Bulletin* 10, p. 119). Eight Scythian burials and one Sarmatian were found in barrow graves at Luparevo south of Nikolaev, east of the liman of the Southern Bug (N. G. Elagina and V. G. Petrenko, *AO* 1969, pp. 234 f.). E. V. Chernenko and E. V. Yakovlenko (*AO* 1969, pp. 239 f.) briefly report on the excavation still further south, near Skadovsk south of Kherson, of 29 barrow graves with 32 Scythian burials (26 of these primary burials); they were mostly looted; only a single one contained more than one skeleton. All were of the 4th century B.C. except barrow 37 in which, in a Scythian secondary burial, a sandstone 'altar-plate' was found typical of the 6th century B.C.

Of a somewhat later date was a Scythian burial excavated in the Eastern Crimea. According to A. M. Leskov (*SA* 1968 (1), pp. 158 ff.), ten barrow graves were excavated there at Ilichevo, which contained jointly about 40 burials, one of these a Scythian burial in barrow No. 1. Close to the burial, a few squashed, damaged golden articles of the first half of the 5th century B.C. were discovered, which presumably originated from it and were lost by its looters. One of these was a cone-shaped object similar to a beaker, with a flat perforated base, undecorated. Others were a solid gold necklace and a thin gold plaque probably designed to be sewn on a garment, covered with a bossed zoomorphic ornament. Finally there was a gold ornamental plaque of a quiver decorated in the same manner in the Scythian animal style.

A number of barrow graves have also been investigated in the west, on the Dniester, as reported by A. I. Meliukova (*AO* 1969, pp. 241 f.). At Nikolaevka near Ovidiopol on the eastern side of the liman, three barrow graves were excavated two of which had two burials; all were of the Late Scythian period. One had two burials in quadrangular shafts, the two other mounds having 'catacomb' type burial chambers. All graves were looted.

The article contains also a very brief report on the excavation of the earthwork Nadlimanskoe (mentioned in *Bulletin* 10, p. 117). It was of the 6th–5th centuries B.C., as indicated by the large number of sherds of Greek imported pottery, many from Hios and Lesbos of the beginning of the 5th century. Local Scythian hand-made ware was also well represented. The earthwork of Roxolany, ancient Nikonia was also investigated. The level of the 5th–4th centuries was excavated. Houses were either built on the ancient surface of the soil, or were slightly sunk in the ground. Those on the surface were built of adobe, and stone was used for that purpose only by the end of the 5th century B.C., the period of the summit of the development of the settlement (N. M. Andrunina, *AO* 1969, p. 236).

Further south, in the region of Kiliya on the lower Danube, at Chervonii Yar, a Scythian barrow grave was discovered. It was one of the group of 9 mounds, 21 m. in diameter; it had a stone circle around its perimeter, and a circular stone cover in the centre under which was the burial shaft 60 cm. deep, 2·5 by 0·75 m. wide on its bottom (A. V. Gudkova, *AO* 1969, pp. 240 f.). The burial was looted and only a few potsherds and stray articles indicate its date as the mid-5th century B.C. However the burial of a horse in an oval shaft dug out close to the main burial shaft was intact. A richly decorated horse harness, with iron bits and cheek-pieces, bronze front-head decoration and several ornamental bronze plaques decorated in the Scythian animal style belonged to the equipment of this burial.

E. F. Pokrovska with two other authors (*AK* 1971 (2), pp. 94–109) describes a settlement of the period 8th–6th centuries B.C., of the Chornolis and the Early Scythian cultures at Khreshchatyk near Cherkassy, situated close to the junction of the Ros with the Dnieper. Of interest is the study by E. V. Yakovenko (*AK* 1971 (2), pp. 87–93) dealing with the muff-shaped censers. Such vessels were already known by the end of the 7th century B.C. at Karmir-Blur; by the end of the 5th and in the 4th centuries B.C. they appear in Kerch, and became very popular in the late Scythian culture in the southern regions of the North Pontic area in the 4th to 1st centuries B.C. Three varieties of the latter type have been distinguished. Another vessel of a special type was dealt with by V. M. Korpusova (*AK* 1971 (3), pp. 75–82), namely the biconic handled beakers of a particular shape. The earliest specimens of this type have been known in the Caucasus, Dagestan in particular, in the 1st century B.C. to 3rd century A.D., but were current there up to the 6th century A.D. In the 3rd century they appeared in the Bosporan Kingdom, evidently taken over by the Bosporan potters, and then by the Cherniakhiv culture.

The issue of *SVOD* D-1-31, *Pamyatniki Skifskogo Vremeni na Srednem Donu* (*Remains of the Scythian Age on the Middle Don*, 1965, 38 pages, 38 plates, a map in the text and a folded chronological graph with all remains typical of the subsequent periods quoted) by P. D. Liberov is missing from *Bulletin* 10, as is also a report by the same author (*KSIAM* 83, 1961, pp. 104–109) on the investigation of two barrow grave cemeteries at Cheremushny near Kharkov. They consisted of 150 mounds of the Late Bronze Age and the Scythian period, nine of which were excavated.

MAP (for numbered sites see list below and opposite)

1 Kiliya, Chervonyi Yar
2 Tyras-Belgorod Dnestrovskii
3 Ovidiopol, Roxolany, Nikolaevka
4 Nadlimanskoe
5 Island of Berezan
6 Olbia
7 Nikolaev, Luparevo
8 Kherson
9 Skadovsk
10 Berislav, Nikolaevka, Kamenka
11 Velika Olexandrivka/Bolshaya Alexandrovka
12 Novo-Rozanovka
13 Ust-Kamyanky, Arkhangelskaya Sloboda, Hrushivka
14 Orjonikidze, Chertomlyk
15 Nikopol, Kuibyshev, Orlova Mogila
16 Ushkalka
17 Balky, Gaimanova Mogila
18 Ianchokrak

19 Zaporozhie
20 Khreshchatyk
21 Supoy peat bog
22 Kharkov, Cheremushny
23 Novocherkassk, Sadovii Kurgan, Konstantinovka
24 Rostov-on-Don, Khutor Fedulova
25 Elizavetovskoe, Selitrennoe, Podazovskoe, kurgan Radutka
26 Tanais-Nedvigovka, Kobiakovo, Nizhne-Gnilovskoe
27 Taganrog
28 Zhdanov-Mariupol
29 Kalos-Limen, Tarpantsi, Ak-Mechet-Chernomorskoe
30 Iuzhno-Donuslavskoe, Mezhvodnoe, Beliaus
31 Eupatoria, Zaozernoe, "Chayka"
32 Chersonese, Sevastopol, Kamyshovaya Bay
33 Alma-Kermen
34 Simferopol
35 Bolshaya Dimitrievka
36 Theodosia-Feodosiya
37 Semenovka, Ilichevo, Novo-Otradnoe, Geroevka
38 Kirovo, Andreevka Iuzhnaya and Severnaya
39 Mikhailovka, barrows Tsarskii (Royal), Kul-Oba, Kara-Oba
40 Panticapaeum-Kerch, Tiritake, Mirmeki
41 Hermonassa
42 Tuzla, Tamanskaya, Artiukhov barrow
43 Nimphaea, Tirambe, Patrey fort
44 Sennaya-Phanagoria, Kepy, Akhtanizovskii barrow-hoard
45 Anapa-Gorgippia, Khutor Rassvet
46 Novorossiisk, Rayevskoe, Myshako, Shirokaya Balka
47 Gelendzhik
48 Cherkessk, Druzhbinskoe
49 Kislovodsk
50 Groznyi
51 Mingechaur
52 Karauzek, Istay-Babay
53 Sazonkin Bugor
54 Aksay
55 Zakanalnyi
56 Volgograd
57 Verkhnee Pogromnoe, Kalinovka
58 Dubovka, Vodianskoe
59 Korolevskoe
60 Voronezh, Chastye Kurgany
61 Rovnoe
62 Nechaevo
63 Krutoyarovka, Novo-Lipovka
64 Lyubimovka
65 Buzuluk, Lipovka, Proskurino
66 Troitskoe
67 Khutor Baryshnikovii, Gerasimovka
68 Ak-Zhar
69 Orsk, Novo-Kumak
70 Alandskoe
71 Kumertau
72 Sterlitamak
73 Karmaskaly
74 Shipovo
75 Ufa
76 Nyrgynda, Dubrovka
77 Gremyachii Kliuch
78 Goriuchalichinskoe
79 Akhmylovo
80 Zaiurchimskoe, Zaosinovskoe, Subbotinskoe earthwork
81 Pershinskoe, Pletnevo
82 Baskoy Loq, Lepiatovskoe
83 Gremiacha, Bolshe Nikolskoe and Kalinovskoe earthworks
84 Tash-Elga
85 Koshibeevskii

A few articles deal with remains of other types, two of them with those of the Milograd culture (see *Bulletin* 10, p. 136). E. O. Petrovska (*AK* 1971 (2), pp. 9–22) describes a variety of the Milograd culture called the Pidhirtsi (Podgortse) culture of the 5th to 3rd centuries B.C. It extended mainly along the valley of the Dnieper from the junction of the Pripet in the north to the region of Kanev in the south. The great impact of the neighbouring Scythian culture on its remains is well recognizable. Another local group of the Milograd culture has been dealt with by I. K. Sveshnikov (*AK* 1971 (2), pp. 68–81). It covered the area on the Horyn in Volhynia, and was of an earlier date (6th to 1st centuries B.C.) than the main group of the culture in Byelorussia on the middle and upper Dnieper.

V. B. Vinogradov (*AO* 1969, pp. 96 f.) and the same author with N. N. Mikhailov (*AO* 1969, pp. 97–99) report on the investigation of three settlements and several flat and barrow grave cemeteries in the region of Kislovodsk in the northern part of Central Caucasus. They were of various periods from the 7th to 5th centuries B.C. to the 2nd and 3rd centuries A.D. and are attributable to various local cultures. A strong Scythian, and later Sarmatian, influence is well reflected on grave goods.

A brief account of the investigation of the earthwork Druzhbinskoe on the upper Kuban near Cherkessk was published by E. P. Alekseva (*AO* 1969, pp. 99 f.). It was in existence from the 5th to 4th centuries B.C. to the 2nd and 3rd centuries A.D. Presumably it was Maeotian.

A. I. Terenozhkin (*SA* 1971 (4), pp. 71–84) discusses the date of the bits from Mingechaur in Azerbaijan which he considers as of the Late Bronze Age. The 'small' barrow grave of the Milskaya steppe situated further to the south has not been properly dated by A. A. Yessen. The author proposes the 7th to 6th centuries B.C. He points out that in Central Transcaucasia iron began to be used for manufacturing tools and weapons only at the beginning of the 7th century B.C., and its wide common use began in the 6th century B.C. Finally should be mentioned the book by O. D. Lordkipanidze, *The Antique World and Ancient Colchis from* 600 *to* 200 *B.C.* (Tbilisi 1966, 228 pages, including 37 plates, in Georgian, with a summary in English pp. 175–184, and in Russian). It deals with commercial and cultural reciprocal connections of ancient Western Georgia with other countries.

Greek colonization

Much has been written and published during the period under review on Greek colonies on the northern coast of the Black Sea and on the coast of the Sea of Azov. A few of these publications are rather of a general character, among them a book *Antichnaya Arkheologiya Severnogo Prichernomoria* (*Classical Archaeology of the North Pontic Area*, Moscow 1961, 230 pages) by V. D. Blavatskii. It contains a general description of all Greek cities of the North Pontic coast including those of the Bosporan Kingdom, of their trade, industries, handicrafts, building craft, art, culture, coins, etc. Another book of this type is the *Festschrift* of V. D. Blavatskii, under the title *Kultura Antichnogo Mira* (*The Culture of the Ancient World*, Moscow 1966, 300 pages, articles by 35 authors. Editor A. I. Boltunova). Its articles deal with a variety of topics relating mainly to the North Pontic area, but some relate to the Aegean area and even to the countries of Soviet Central Asia.

The well produced book, *Antichnii Gorod* (*Ancient City*, Moscow 1963, 192 pages, profusely illustrated. Editor A. I. Boltunova) contains 15 articles by 15 authors that give a brief characteristic of all main Greek cities of the North Pontic coast. The book *Znaniya Drevnikh o Severnykh Stranakh* (*The Knowledge of the Ancients of the Northern Countries*, Moscow 1961, 224 pages, 28 illustrations in the text) by L. A. Elnitskii discusses the ancient written records relating to the North Pontic area; and I. B. Brashinskii, in his paperback *Afiny i Severnoe Prichernomorie v VI–II vv. do n.e.*

(*Athens and the North Pontic Area in the 6th to 2nd centuries B.C.*, Moscow 1963, 176 pages, several unnumbered illustrations) discusses the relations of Athens to the countries on the northern Black Sea coast in the period mentioned above.

Mention should also be made of two important studies which appeared in Germany. One is the collection of papers read at a special conference in East Berlin under the title *Griechische Städte und einheimische Völker des Schwarzmeergebietes* (Berlin 1961, 163 pages, 17 papers by 17 authors. Deutsche Akademie der Wissenschaften) and in particular its paper by L. Zgusta (pp. 159–163), 'Die verschiedenen Bevölkerungsschichten der griechischen Städte des nördlichen Schwarzmeergebietes', in which the author supposes that some remnants of Thracian tribes may have survived in the North Pontic area up to the Scythian period. The other publication is the study by Ch. M. Danoff, 'Pontos Euxeinos' in the *Realencyclopädie Pauly-Wissowa* (vol. IX, Stuttgart 1962, columns 865–1175). It contains a very competent geographic economic and historical description of the countries around the whole coast of the Black Sea, including the Greek North Pontic colonies.

Controversial views have been expressed by several scholars as regards the aim of the ancient Greek colonization along the coasts of the Black Sea. According to Ia. V. Domanskii (*ASE* 7, 1965, pp. 116–141) it was the outcome of the migration of the surplus population from the Greek cities in the Aegean. Archaeological evidence and written records show that in the early period, the 7th to 5th centuries B.C., the trade of the colonies with Greece was on a very modest scale. During the early stage a few emporia (trade factories) were the centres of barter trade with the local people but they did not have the character of permanent colonies; only some of these later became transformed into proper colonies.

Similar opinions were expressed by other scholars. Thus V. V. Lapin, in the work *Grecheskaya Kolonizatsiya Severnogo Prichernomoriya* (*Greek Colonization of the North Pontic Lands*, Kiev 1966, 40 pages) discusses some aspects of Greek settlement in that area, and maintains that its commercial character has been over-emphasized by the authors concerned; this was first of all an agrarian colonization. The book was censured in the review by Iu. N. Zakharuk and A. Terenozhkin (*SA* 1968 (4), pp. 287–290; 290–297). The thesis above has already been put forward by V. V. Lapin in an earlier article (*AK* XIV, 1962, pp. 17–30).

The trade of the colonies, Olbian trade in particular, has been the theme of several articles by various scholars. Thus M. M. Bondar (*AK* XI, 1957, pp. 35–44; XIII, 1961, pp. 80–88) discusses Olbian maritime trade with other Greek colonies on the Black Sea coast, and with the Greek towns in the Aegean and in the basin of the eastern Mediterranean. Olbian trade with her Hinterland, the middle Dnieper and the lower Southern Bug countries, was the theme of several publications by N. A. Onayko, who treated separately that of the 7th to 5th centuries B.C. (*SA* 1960 (2), pp. 26–41; *SVOD* D-1-27, 1966, 70 pages, 24 plates, 294 items), and that of the 4th to 2nd centuries B.C. (*SA* 1962 (1), pp. 66–82; *SVOD* D-1-27, 1970, 128 pages, 45 plates, 860 items). Commercial connections of probably Greek settlements on the liman of the Dniester

with Greece at the time from the 6th to 2nd centuries B.C. have been reviewed by O. G. Salnikov (*MASP* III, 1960, pp. 25–32, IV, 1962, pp. 61–72) and I. B. Brashinskii (*SA* 1968 (2), pp. 260 ff.) also contributed to the study of the Olbian commercial connections. A good illustration of Olbian commercial activities is the important hoard of 12 bronze vases of Mediterranean origin of the 5th century B.C. discovered a few years ago in the peatbog of the Supoy, a left tributary of the middle Dnieper. It was found in a dugout together with a human skeleton. It has been briefly reported by O. D. Ganina (*AK* XVI, 1964, pp. 195–197). Trade of other North Pontic colonies and of the Bosporan Kingdom as a whole has been dealt with jointly with other topics in several books and articles mentioned below. It may be mentioned that agonistic amphorae found in the necropoli situated in the North Pontic regions have been discussed by J. G. Shurgaya (*SA* 1971 (3), pp. 189–202), who concludes that they are mostly from Alexandria and Pergamum. Heraclean amphorae found in the Crimea have been dealt with by O. A. Makhneva (*SA* 1969 (4), pp. 257–259), and V. I. Pruglo (*SA* 1971 (3), pp. 76–90) deliberates on the chronology of pottery-stamps of Heraclea Pontica and disagrees with their dating proposed by I. B. Brashinskii. N. O. Leypunska (*AK* 1971 (3), pp. 67–74) proposes a method of typological classification of Greek amphorae based on the North Pontic material of the last centuries B.C., and produces examples of its application.

V. F. Gaidukevich (*KSIAM* 116, 1969, pp. 11–19) discusses navigation of the Athenian Navy on the Black Sea around 400 B.C., and shows, against some other scholars, that this was no coastal navigation, but that the Greeks at a much earlier date had already regularly sailed across the Black Sea, from south to north and in the opposite way.

I. T. Kruglikova (*KSIAM* 124, 1970, pp. 3–11) debated on religious representations of the rural population of the Bosporan Kingdom and on their changes during the period from the 5th century B.C. to the 3rd century A.D. She emphasizes that changes during that time of the types of the female figurines (idols), shown in two figures arranged in their chronological order, and also changes in the burial ritual that took place in the meantime, are the expression of the changes in the beliefs of the population. Their variety implies a mixed composition of that population. A cross and fish engraved on a ring of the 3rd century A.D. indicates that Christianity must have reached the country at that time.

The influence which during the periods from the 7th to 5th centuries B.C. and from the 4th century B.C. to the 3rd century A.D. the ancient Greek culture of the North Pontic colonies had exercised on peoples of the wide Hinterland has been discussed by V. D. Blavatskii (*SA* 1964 (2), pp. 13 ff.; 1964 (4), pp. 25–35). Examples are votive scenes carved in relief in limestone usually representing three human figures, several of which were found in the southern area of the North Pontic country. They were discussed by A. P. Mantsevich (*KSIAK* 11, 1961, pp. 10–19) according to whom they were mainly of the 4th century B.C. and were probably inspired by the Thracians.

The viniculture well attested in several regions of the Crimea in the 4th to 3rd

centuries B.C., was undoubtedly introduced by the Greeks, as shown by E. V. Veymarn (*KSIAK* 10, 1960, pp. 109–117).

A few books specialize in some particular trades. One of these is *Keramicheskoe Proizvodstvo i Antichnye Keramicheskie Stroitelnye Materialy* (*Ceramic Production and Classical Ceramic Building Materials*, *SVOD* G-1-20, 1966, 160 pages including 46 plates) by seven authors. This is a catalogue of kilns and moulds for the production of ceramic ornaments, figures, decorative friezes, etc., found within the area of the Greek colonization. Of interest is a marble potter's wheel found at the Roxolany earthwork on the Dniester liman, reported by A. A. Bobrinskii (*SA* 1966 (3), pp. 235–240) considered to be of the late centuries B.C. Some specific features of Greek pottery were the theme of a few recent studies. Thus V. I. Tsekhmistrenko (*KSIAM* 128, 1971, pp. 15–20) deliberates on the character and purpose of stamps and stamping antique pottery; and the study by I. D. Marchenko (*KSIAM* 128, 1971, pp. 21–32) is devoted to the imported Greek glazed earthenware found mainly in Greek North Pontic colonies. Such a vessel found in the Iuzhno-Donuzlavskoe earthwork in the Western Crimea was described in detail by A. S. Golentsov (*KSIAM* 128, 1971, pp. 63–65. To another theme is devoted the well produced book *Derevoobrabatyvayushchee Remeslo v Antichnykh Gosudarstvakh Severnogo Prichernomoriya* (*The Handicrafts working in wood in the Ancient States of the North Pontic Area*, Moscow 1971, *MIA* 178, 290 pages, XXXVII plates, 78 figures in text) by N. I. Sokolskii, in which all kinds of ancient wooden objects have been taken into account and described and their purpose, the manner of their making and technique etc. discussed. Another similar study by the same author is *Antichnye Derevyannye Sarkofagi Severnogo Prichernomoriya* (*Ancient Wooden Sarcophagi of the North Pontic Area*, Moscow 1969, *SVOD* G-1-17, 192 pages, including 48 tables). Olbian, Bosporan and Chersonesian sarcophagi have been described, their details discussed, and then the specimens dated. An article by the same author (*ZOAO* I, 1960, pp. 124–132) has been devoted to small clay boxes of the 3rd century A.D. found mainly in Panticapaeum and its neighbouring sites, several of them in graves. They call to mind small sarcophagi. The author discusses their purpose.

M. P. Vaulina (*SA* 1970 (3), pp. 228–232) describes fragments of a wooden sarcophagus of the second half of the 2nd century A.D., with a carved cornice found in Kerch, and S. S. Bessonova (*SA* 1971 (4), pp. 215–221) gives a detailed description of the remains of a sarcophagus made of wooden planks found in a stone slab cist in one of the Tri Brata barrows in Kerch, and produces its reconstruction. Two skeletons, one male and one female, were found in this grave which was of the second half of the 4th century B.C.

Finally, the book *Kultura i Iskusstvo Antichnogo Mira* (*Culture and Art of the Antique World*. Leningrad 1971, 130 pages), deserves mention; it contains separate contributions by 11 authors, dealing mainly with Greek ancient vases, but also with the sarcophagi and other finds, some from barrow graves from the south of Eastern Europe. A few articles discuss finds from other regions of the Mediterranean.

Reports on excavations

A manual by V. D. Blavatskii, *Antychnyaya Polevaya Arkheologiya* (*Classical Field Archaeology*, *MIA* 146, 1967, 208 pages), contains instructions relating to the organization, methods and management of excavation, of preparing the publication of the results, suggestions as to how to draw conclusions, etc. There is a large bibliography on the subject added.

A report of the results of excavations, mainly in 1957, on behalf of the Institute of Archaeology of the Soviet Academy in Leningrad, has been published by V. F. Gaydukevich, S. I. Kaposhina and E. I. Levi (*KSIIMK* 78, 1960, pp. 85–89). In Olbia a large building has been uncovered on the Agora, of the 4th century B.C., and fragments of marble plates were found with inscriptions. On one of these was a decree of the 4th century B.C. attesting to close Olbian connections with Chersonesos in the 4th to 3rd centuries B.C. At Mirmeki defensive walls of the 3rd century B.C. have been uncovered and also some other constructions. Investigations were also made at the sites of Tiritake, 11 km. south of Kerch, and of Ilurat, 17 km. west of that city, where a house of the 2nd to 3rd centuries A.D. was uncovered. At Kiteya, 40 km. south of Kerch, a defensive wall and a few smaller items were investigated. Outside the Crimea, the earthwork of Kobiakovo near the mouth of the Don was investigated and a few huts were uncovered. In the cemetery of Kobiakovo 34 graves were excavated in 1956, and 88 in 1957; they were mostly of the 1st to the 3rd centuries A.D.

Mention should also be made of a series of articles by V. D. Blavatskii, some jointly with other authors, containing brief reports on underwater explorations at several points along the Black Sea and Azov Sea coast, namely at Fanagoria (*KSIAM* 83, 1961, pp. 136–138; *SA* 1961 (1), pp. 277–279; 1969 (3), pp. 151–158), on the southern Crimean coast and the region of Taganrog and Zhdanov on the Sea of Azov (*SA* 1961 (4), pp. 148–157), Olbia (*SA* 1962 (3), pp. 225–234), and the region of Belgorod-Dnestrovskii, ancient Tyras (*SA* 1965 (1), pp. 272–275).

A number of monographs bring the results of the investigation of a series of the individual Greek North Pontic cities, and quite a large number of articles in various periodicals contain either preliminary reports on excavation or deal with some special topics relating to these cities. We shall briefly review these publications starting with those in the west, gradually proceeding eastwards.

Tyras

The westernmost colony of our area was Tyras (modern Belgorod-Dnestrovskii) on the western side of the liman of the Dniester, around which several indigenous settlements were set up, dealt with in my previous reports (*Bulletins* 8/9, p. 126; 10, p. 117). The results of the excavation of the relics of the city of the 3rd century onwards were reported by A. I. Furmanskaya (*SA* 1959 (2), pp. 60 ff.; 1960 (4), pp. 173ff; *AP* XI, 1962, pp. 122–137), and a brief summary of these, up to 1962, was later published by the same author (*KSAMO* for 1962, Odessa 1964, pp. 56–63). Two articles, likewise by A. I. Furmanska (*KSIAK* 10, 1965, pp. 78–83; *AK* XIX, 1965, pp. 158–

164) are devoted to a few sculptures, some in relief, found in the ruins of a house of the 2nd to 3rd centuries A.D.

Berezan

Next to the east is the small island of Berezan, situated close to the liman of the Southern Bug, south of it; this was the earliest Greek trading factory in the North Pontic area, known so far. Brief outlines of its history have been sketched by M. F. Boltenko (*ZOAO* I, 1960, pp. 38–46). The earliest pottery found in the island was of Rhodos ware of the period from *c.* 635 B.C. to the mid-6th century B.C.; it has been discussed by V. M. Skudnova (*SA* 1960 (2), pp. 153–167).

A few preliminary reports on recent excavation of the Greek settlement have been published by V. V. Lapin (*KSIAK* 11, 1961, pp. 43–52; *AIU* 1967, pp. 145–149 with a folded plan) on the results of the campaigns of 1960 and 1966, and by K. S. Gorbunova (*AO* 1966, pp. 206 f.; 1967, pp. 207 f.; 1968, pp. 272 f.; 1969, pp. 247) on the excavation in 1966 and 1968 of the settlement and in 1967 of the cemetery. All remains were of the time from the 7th to 4th centuries B.C., and little has been found from later periods. The hand-made pottery of the 7th to 6th centuries B.C. from Berezan has been dealt with by G. O. Dzis-Rayko (*MASP* II, 1959, pp. 36–43); E. F. Yarovaya (*KSAMO* for 1961 [1963], pp. 16–19; for 1962 [1964], pp. 134–136) deliberates on a painted Clazomenae vase of the first half of the 6th century B.C. Finally, P. O. Karyshkovskii (*KSIAK* 9, 1959, pp. 85–89) classifies the 28 coins found on the island of Berezan, and their specification is given on a graph; the earliest were of the turn of the 6th and 5th centuries B.C., the latest from the 17th to 18th centuries A.D.

Olbia

A few larger volumes are devoted entirely to Olbia, and a large number of articles deal with a variety of problems relating to that city. One of the largest is the volume *Olvia—Temenos i Agora* (*Olbia, Temenos and Agora*, Moscow–Leningrad 1964, 383 pages, editor V. F. Gaydukevich) by 10 authors, and another one, *Nadpisi Olvii* (*Inscriptions of Olbia*, Leningrad 1968, 133 pages, 65 plates), introduction by E. I. Levi, the authors of the text not being named. The book *Zilye Ansambli Drevney Olvii 4–2 vv. do n.e.* (*Complexes of Olbian Dwelling-Houses, Dwelling Ensembles of Ancient Olbia of the 4th to 2nd centuries B.C.*, Kiev 1971, 144 pages) by S. D. Kryzhitskii, contains descriptions of houses of the Hellenistic period, the reciprocal relation between the different schools of architecture in Olbia and in Greece, their traditions, and the city's plan, etc. The 12 articles by 12 authors of the vol. *AP* VII (1958, 160 pages) are also devoted only to topics connected with Olbia. A brief history of the investigation of ruins of ancient Olbia has been written by L. M. Slavin (*ZOAO* I, 1960, pp. 47–59). An article by K. K. Shilik (*KSIAM* 124, 1970, pp. 109–114) is devoted to the reconstruction of the city's topographic position.

Several preliminary reports on excavations of the Olbian relics have been pub-

lished by several authors. Those of 1958 were reported by V. V. Lapin (*MASP* IV, 1962, pp. 163–176), and the results of 1960–1962 by A. N. Karasov and E. I. Levi (*KSIAM* 103, 1965, pp. 80–93) and by Brashinskii (*KSIAM* 103, 1965, pp. 94–100). The results of earlier investigations, up to 1944, were briefly summarized by L. M. Slavin (*AP* XI, 1962, pp. 3–32), and the same author reported also on excavations in 1965–66 and 1969 (*AIU* pp. 121–126; *AO* 1969, pp. 250 f.). In the first quoted publication of these two, a summary of the results of the excavation of some other parts of the ancient city in 1965–1966 was published by three authors, S. D. Krizhitskii (pp. 131–133), R. I. Vetshtein (of the citadel, pp. 134–137) and by N. A. Leypunskaya (of Agora, pp. 138–141). Excavation of both the ruins and the city and its cemetery of the period from the 1st to 2nd centuries A.D. in 1965, 1966 and 1968, were briefly reported by Iu. I. Kozub (*AIU* pp. 126–130; *AO* 1966, pp. 207–210; 1968, pp. 282–283). He also mentions that the Olbian archaeological material has been divided into three chronological groups: of the 6th to 5th centuries B.C.; the 4th to 3rd; and of the time from the 2nd century B.C. to the 3rd century A.D. Some architectural details, chiefly a number of capitals excavated in Olbian Agora in 1962–63 were described by S. D. Kryzhytskyi (Krizhitskii) (*AK* XIX, 1965, pp. 165–176), who also deliberates (*AK* XXII, 1969, pp. 90–119) on the remains and foundations of a number of large dwelling-houses of the period from the 5th to the 3rd centuries B.C., uncovered at Olbia, and discusses their plans, details of their construction, their architecture, etc. The article is provided with several plans and reconstructions in drawings of many houses. Similar topics relating to the Olbian dwelling-houses of the Hellenistic period, their height, number of storeys, etc, have been discussed by the same author in a recent article (*AK* 1972(1) pp. 56–68).

V. F. Petrun (*AK* XIX, 1965, pp. 138–157) presents the results of his study of the stone building material; mainly the local limestone was used, but also stone imported from Greece of three main varieties: magmata, sedimentary rocks, and metamorphic rocks of various types. R. I. Vetshtein (*AK* XVIII, 1965, pp. 206–208) describes a large pottery kiln for firing tiles, and G. M. Melentieva (*KSIAM* 116, 1969, pp. 23–28) discusses the representative types of vessels of the Olbian pottery complex of the early centuries of the Christian era, in particular amphorae of the 3rd and 4th centuries A.D.

Excavation of the Olbian cemetery in 1956 has been reported by A. I. Furmanskaya (*KSIAK* 8, 1959, pp. 133–138), and previous excavations of the cemetery, up to 1955, have been briefly reviewed by M. B. Parovych (*AP* XI, 1962, pp. 33–38). The latter author also deliberates on special features of the various parts of the cemetery used in different periods, and the connection of these changes with the changing position of the city itself. Burial rites of the 5th to 4th centuries in Olbia and the varied sepulchral constructions of that period have been discussed in two articles by Iu. I. Kozub (*ZOAO* I, 1960, pp. 75–84; *AP* XI, 1962, pp. 39–48). A special study by the same author (*AK* XIV, 1962, pp. 116–134) has been devoted to the *lekythi* of the 5th to 4th centuries B.C. excavated in the Olbian cemetery. Finally, V. M. Skudova

(*ZOAO* I, 1960, pp. 60–74) deals with Olbian graves of the earliest period (6th to 5th centuries B.C.) excavated in 1909–1913, in which weapons were found, iron swords, daggers of the Scythian type, arrow-heads, lance-heads, etc. She emphasizes that warriors buried in these graves were evidently Olbian Greeks, not Scythians.

E. G. Kastanyan (*KSIAM* 103, 1965, pp. 38–40) debates on three unpublished Olbian inscriptions of the period between the first and the 2nd to 3rd centuries A.D., with non-Greek, probably North Caucasian names; and T. N. Knipovich,(*KSIAM* 116, 1969, pp. 20–22) points out some special features of the style of lapidar letters of Olbian inscriptions.

General questions

A few articles are of a more general character. V. L. Zuts (*AK* XIX, 1965, pp. 36–46) deliberates on the date at which Olbia began to constitute an independent state, and concludes that this was the mid-6th century B.C., the time at which the earliest Olbian coins, the bronze 'dolphins' were issued. Other studies by the same author (*AK* XXII, 1969, pp. 80–89) are devoted to the establishment of the extent of the territory ruled by Olbia, or dependent on the city politically, and (*AK* 1971 (3), pp. 22–25) to the aspect of Olbian property rights in the 4th to 1st centuries B.C. P. I. Karyshkovskii (*AK* XXI, 1968, pp. 95–105) discusses the date of the Decree in honour of Protogenes. He thinks that this was the first decade of the 2nd century B.C. The same author (*MASP* II, 1959, pp. 67–79) also discusses the external relations of Olbia, in particular with Rhodos, which are well attested by Rhodian coins of the 3rd century B.C. found in Olbia (*KSIAM* 83, 1961, pp. 9 ff.), and devoted articles to Olbian coins, one of the Hellenistic period (*MASP* IV, 1962, pp. 87–107), the other (*AK* 1971 (4), pp. 79–84) dealing with Olbian silver coins of the 1st century A.D. and its silver monetary system, which is of importance for the chronology of the transition from the Greek to the Roman monetary system.

A few articles deal with objects connected with ancient cults. A. S. Rusayeva (*AK* 1971 (4), pp. 28–40) discusses the worship of the goddess Kore-Persephoneia, daughter of Demeter, in Olbia ,which she illustrates by a series of terracotta figurines found in Olbia. Another one, the worship of Apollo in Olbia in the 2nd and 3rd centuries A.D. was the theme of the study by N. O. Leypunska (*AK* XVI, 1964, pp. 21–26) who later (*AK* XXIII, 1970, pp. 60–73) devoted her attention to the Olbian worship of Achilles; there were two aspects of his cult, the earlier one, of Achilles of the Island of Levki (Leuke), and the later aspect, of Achilles Pontarchus, whose cult was widespread in the North Pontic coastal area in the later periods. I. B. Kleiman deliberates on the sculptures in relief from Olbia representing the Gratiae (*MASP* IV 1962, pp. 234–240), and on their meaning; and E. I. Levi (*KSIIMK* 74, 1959, pp. 9–19), discusses the terracotta figurines found in a cistern on the Agora; the figurines, among which were also those of Kibela, had a votive character and were of the second half of the 4th century B.C. Of interest is a small leaden triple figurine ('germa') found in 1955, which according to E. O. Petrovska (*AK* XI, 1957, pp. 154–156) represents

Hermes, Priapus and Aphrodite, and was from the period of about the end of the 5th to 4th centuries B.C. The type represented by the figurines is a very rare occurrence. Finally a marble female head may be mentioned, published by V. V. Lapin (*KSIAK* 9, 1960, pp. 80–84), the date of which has been estimated as the late 4th or rather 3rd century B.C.

A few short articles are devoted to some special objects imported from Athens and the Aegean islands, which at the same time attest to wide Olbian commercial connections. Thus K. S. Gorbunova (*SA* 1963 (3), pp. 297–301) deals with a *krater* found in Olbia, made by the master-craftsman Didos in the 6th century B.C.; I. B. Brashinskii (*SA* 1965 (3), pp. 225–228) describes an Ionian- and other imported-vessels, in particular a Clazomenae hydria of the 6th century B.C., and F. M. Shtitelman (*SA* 1965 (4), pp. 223–227) describes a silver medallion with the image of Athene, of the 2nd century B.C., which was found in a pit together with Greek pottery.

A number of papers deal with the Olbian coinage and monetary system. O. G. Salnikov (*MASP* II, 1959, pp. 44–66) describes and classifies the earliest Olbian 'coins' in the shape of fish ('dolphins'), and establishes their chronology: they first appeared at about 570 to 560 B.C. In another article he discusses the gold coins in the collection of the Archaeological Museum at Odessa. They were found in the North Pontic colonies, mainly in Olbia. A series of articles on Olbian coins and on topics connected with them, were published by P. O. Karyshkovskii. He deliberates on the legend of the earliest Olbian coins, including the 'dolphins' (*MASP* II, 1962, pp. 220–227), and discusses Olbian coins of the Hellenistic period (as above, pp. 87–107, and *AK* XI, 1957, pp. 45–69); in pointing to the changes in the monetary system in Olbia in the 4th century B.C., he discusses its reasons and consequences. Economic relations between Olbia and the Bosporan state in the 4th to 3rd centuries B.C., and also similar relations in the Christian era, were the theme of another article (*KSAMO* 1964, pp. 139–145), and a special study (*ZOAO* I, 1960, pp. 112–123) is devoted to the history of the monetary turnover in the North Pontic lands in the 3rd century B.C. In listing and describing a series of gold coins of Lysimachus, and Macedonian gold coins, all found in Olbia, P. I. Karyshkovskii deliberates on the political situation of the country at that time and points out that the archaeological material attests to close connections of Olbia of that time with ancient Greek cities on the western coast of the Black Sea, and with the Getae and Dacians. Finally the same author (*AP* XI, 1962, pp. 102–121) discusses the Scythian coins minted in Olbia in the 2nd and 1st centuries A.D., establishes their proper date and discusses also the political conditions, the circumstances in which Olbia was at that time, and the Scytho-Olbian relations. The same was the theme of an article by A. G. Salnikov (*ZOAO* I, 1960, pp. 85–95).

According to D. B. Shelov (in *Drevnosti Vostochnoy Evropy*, *MIA* 169, 1969, pp. 296–299), a number of Olbian copper coins of the end of the 4th and 3rd centuries B.C. were found in the country on the lower Volga. Among these was an Olbian coin found together with two Panticapaean at Rovnoe near Saratov; one at Vodianskoe

earthwork, north of Dubovka, and three Hellenistic Olbian coins were found somewhere between Saratov and Astrakhan. In that area also other coins were found, silver and bronze, of Alexander of Macedonia, Athenian, Panticapaean, Phanagorian and Chersonesian. All these coins found their way to the Volga via the mouth of the Don, as suggested by an Olbian coin (Boristenus) found in the earthwork of Elizavetovskoe, and another one of the same period at the earthwork of Selitrennoe further east of the latter. They undoubtedly mark an ancient trade route which was interrupted in the second half of the 3rd century B.C. It is of interest to note in this context that somewhere in the country around Kherson, which also included Olbia, two Bactrian coins were found mentioned by A. H. Zahynaylo (*MASP* III, 1960, pp. 250–252). One of these, of Eukratidos (3rd century B.C.), was found at Velika Oleksandrivka, but the site in which the other was found has not been established.

Finally, M. B. Parovych (*AK* XI, 1957, pp. 157–159), who listed all Olbian coins with the head of Tikh(?) stamped on them, shows that they were found mostly in burials of the very end of the 4th and 3rd centuries B.C.; accordingly, this seems to have been their approximate date. Of special interest was a vase found at Mirmeki, described by V. I. Pruglo (*MASP* IV, 1962, pp. 73–86) in the side wall of which a small copper coin was found; the author quotes several cases with a similar occurrence, where a small copper coin was put into the clay paste before firing the vessel.

Chersonesus

During the period under review a few reports on excavation of the ruins of Chersonesus were reported. Those in the period 1946–1950 were summarized by G. D. Belov (*IADK*, pp. 238–248). The description of excavations in 1954–1958, especially of a theatre, the study of several architectural details, of new inscriptions etc. may be found in *Soobshcheniya Khersonesskogo Muzeya* I, Simferopol 1960 (the only issue available in London), which contains 15 articles on various topics relating to Chersonesus, by 8 authors. G. D. Belov also published two short reports on the results of excavation of relics of the city in 1967 and 1968 (*AO* 1967, pp. 218 f.; 1968, pp. 284 f.), and of the city's defensive wall (*AO* 1969, pp. 248 f.); a similar report on the citadel was published by T. N. Vysotskaya (*AO* 1969, pp. 252 f.). G. D. Belov, (*SA* 1965 (3), pp. 237–239; *KSIAM* 116, 1969, pp. 80–84) also described remains of glassworks at Chersonesus active during the period from the 4th to the 6th centuries A.D., and produced the analyses of its glass products.

Several anthropomorphic stelae found in Chersonesus were described and discussed by A. N. Shcheglov (*SA* 1963 (2), pp. 213 ff. *AK* XXI, 1968, pp. 214–221) who also points to their specific features. They were all of the period from the 2nd century B.C. to the 4th century A.D. A special category of marble or limestone stelae with scenes carved on them in relief representing afterlife meals, was dealt with by G. P. Ivanova (*AK* XXIII, 1970, pp. 74–90). A. N. Shcheglov (*AO* 1968, pp. 290 f.; 1969, pp. 257 f.) also describes remains of several buildings of the period from the 3rd to 2nd centuries B.C. to the 1st century A.D., uncovered along the sea coast at

Sevastopol, within the ancient northern periphery of Chersonesus, and A. M. Gilevich (*AO* 1968, pp. 285 f.) describes a hoard of silver and copper coins of the period from the end of the 4th to the early 2nd centuries B.C. found in a clay vessel near the Kamyshovaya bay in Sevastopol.

Chersonesus countryside

Several articles report on the results of investigations of Greek settlements founded by the Chersonesus along the western coast of the Crimea north of the city, up to the westernmost point south-west of Chernomorskoe (formerly Ak-Metchet). They were mostly fortified (earthworks), built in the 4th to 3rd centuries B.C., and by the mid-2nd century B.C. were mostly burned and seized by the Scythians. Subsequently the Scythians settled in several of these and some became Scythian strongholds, but by the end of the 2nd, or in the 3rd century A.D., they were seized by the Goths and for the most part destroyed by them.

One of the earthworks investigated lay on the periphery of Eupatoria (Sanatorium 'Chayka'). It was constructed in the 5th century B.C. on the site of a Greek trade-factory, and destroyed by the Scythians in the 2nd century B.C.; it was then held by them till the end of the 2nd century A.D. Reports on its excavation were published by A. N. Karasev (*KSIAM* 95, 1963, pp. 33–42; 103, 1965, pp. 131–139; *AO* 1965, pp. 115–117; 1966, pp. 291–294) and by I. V. Iatsenko (*AO* 1969, pp. 253–255; *KSIAM* 124, 1970, pp. 31–38). The geomorphology of the site was described and its pollen-analysis published by P. M. Dolukhanov (*KSIAM* 124, 1970, pp. 99–101) and G. M. Levkovskaya (*KSIAM* 124, 1970, pp. 102–108). Further to the north-west two earthworks were investigated on the Donuslav Sea, close to the narrow strip of land barring it from the open sea; one of these, Iuzhno-Donuslavskoe, was situated on the southern, the other, Belyaus, on its north-western tips by the sea. Preliminary reports on their investigation, and on excavation of the Scythian cemetery of the 3rd to 1st centuries B.C. that belonged to the second of these, were published by O. D. Dashevskaya (*KSAMO* for 1962, Odessa 1964, pp. 50–56; *AO* 1965, pp. 118–120; 1966, pp. 212–214; 1967, pp. 215–217; 1968, pp. 297–299; 1969, pp. 256 f.; *KSIAM* 103, 1965, pp. 148–152) and by the same author jointly with A. N. Shcheglov (*SA* 1965 (2), pp. 246 ff.). Preliminary reports on investigations of rural settlements and of two other Greek earthworks built in the 4th century B.C. (destroyed by the Scythians in the 2nd century B.C.) at Kalos-Limen and Tarpantsi (north-west of the first of these), both on the westernmost tip of the Crimea, were published by A. N. Shcheglov (*AO* 1966, pp. 210–212; *SA* 1967 (3), pp. 234–256; *KSIAM* 103, 1965, pp. 140–147); a Scythian stronghold was constructed on the site of the latter, which was a Greek earthwork. Excavation of Kalos-Limen in 1948–1952 were briefly summarized by M. A. Nalivkina (*IADK*, pp. 264–281).

In the same region, at Mezhvodnoe, a stone slab was found with a sculpture in relief of Heracles, and excavation—reported by T. N. Vysotskaya (*AO* 1967, pp. 211 f.; 1968, pp. 295 f.)—revealed that a Greek settlement of the 4th to 3rd centuries B.C.

had previously existed at that site. Foundations of a large building of stone, pottery and other remains were found. The settlement was destroyed in the 2nd century B.C., probably by the Scythians. O. D. Dashevskaya (*KSIAM* 116, 1969, pp. 85–92) describes a dungeon square in plan, the foundation of which and the lowest part of its walls were uncovered in the earthwork of Beliaus in the north-west Crimea, 41 km. north-west of Evpatoria. It was built in the 4th century. The site lay on the border of the Chersonesus territory, in the territory under the rule of that city.

A. A. Konovalov (*AO* 1969, pp. 255 f.) reports on the investigation of the necropolis of the 4th to 3rd centuries B.C. near the village of Zaozernoe. Also excavated was a barrow grave situated in the western part of the cemetery. It had a stone ring around its perimeter. The grave with a double burial was lined with large stone slabs, partly sunk in the ancient ground (a rock). The date of the grave has been indicated by a Chersonesian amphora of the second half of the 4th century B.C.

Two articles are of a general character. One of these, by V. I. Kadeev (*AK* XIII, 1961, pp. 89–94) is devoted to the saline industry in Chersonesus in the 1st to 4th century A.D., and in the other V. O. Anokhin (*AK* XIV, 1962, pp. 31–51) deliberates on the chronology of the Chersonesian ('Tetrasarii') coins from A.D. 138–295, and their variants, giving also a brief review of the history of Chersonesian coinage and monetary system. It should also be mentioned that near the strip of land barring the Donuzlav liman from the sea (Donuzlavskaya kosa) remains of a merchant ship were found on the sea bottom, as reported by V. D. Blavatskii and B. G. Peters (*AO* 1965, pp. 131–132), loaded with wine and oil amphorae of the 3rd century B.C. According to V. I. Kadeev and V. I. Vishnevskii (*AO* 1966, p. 257), remains of a similar ship of the 1st century A.D. have been found on the bottom of the Pesochnaya Bukhta near Chersonesus, and were likewise investigated. It is of interest to note, as mentioned by A. N. Shcheglov (*AO* 1967, p. 214), that at the time around the turn of the Christian era the sea level was 2–3 m. below the present one. Finally, the article by N. V. Pyatisheva (*IADK*, pp. 249–263) is devoted to the study of the Scytho-Chersonesian relations, in which two distinct periods may be distinguished, the first one from the end of the 5th to the mid-2nd centuries B.C., the other from the mid-2nd century B.C. to the 4th century A.D.

The Bosporan Kingdom

There are a few publications of a rather general character. To these belongs the study *Bospor v Pozdne-antichnoe Vremya—Ocherki Ekonomicheskoy Istorii* (*The Bosporus During the Late Classical Period—A Sketch of the Economic History*, Moscow 1966, 224 pages) by I. T. Kruglikova. The book, as indicated by its sub-title, is a brief and popular outline of the economic history of the Bosporus. A more detailed study of the political conditions in the Bosporan kingdom at the turn of the Christian era is contained in two articles by T. V. Blavatskaya (*SA* 1965 (2), pp. 197–209; 1965 (3), pp. 28–37).

I. B. Brashinskii (*VDI* 1958 (3), pp. 114 ff.) emphasizes the importance of the

trade in cereals and fishes for the Bosporan economy in the 4th century B.C. The agricultural character of the Bosporan economy during the 4th to 1st centuries B.C. has also been pointed out by V. D. Blavatskii (*SA* XXIX–XXX, 1959, pp. 42–57), according to whom besides agriculture, the Bosporan handicrafts were highly developed; workshops of various kinds—potteries, weaving, stone-building crafts—flourished in almost all Bosporan towns, but only in a few rural settlements. In the volume *Keramicheskaya Tara Bospora* (*The Bosporan Pottery Tare*, *MIA* 83, 180 pages, 41 tables), I. B. Zees deliberates on Bosporan allowances made for weight of vessels in which wine and other liquids were transported. The same author also deliberates on the imported tiles of the 6th to 5th centuries B.C. found mainly in Panticapaeum. They were of Athenian origin but were likewise imported from Corinthus and other Greek and Mediterranean cities, but also from Amisus and Sinope on the southern coast of the Black Sea. It is only by the end of the 5th century B.C. that local, Bosporan tiles were produced. A special study by N. I. Sokolskii (*KSIAM* 116, 1969, pp.59–67) is devoted to the pottery industry in the eastern, Asiatic, part of the Bosporan Kingdom; all the hitherto uncovered centres of pottery production, kilns, etc. in that area of the period from the 4th century B.C. to the 3rd century A.D. have been quoted; and I. D. Marchenko (*SA* 1967 (2), pp. 146 ff.) pays attention to the local Panticapaean painted pottery of the 6th and 5th centuries B.C.

I. G. Shurgaya (*KSIAM* 103, 1965, pp. 41–44) discusses the Pergamon import of the 2nd century B.C. in the Bosporan Kingdom, and also deliberates (*MASP* IV, 1962, pp. 108–120) on the so-called Megarean vases with a decoration in relief, of the 3rd to 1st centuries B.C., found within the Bosporan territory, and shows that for the most part they were a product of local Bosporan workshops. In this, she follows the opinion expressed a few years earlier by V. D. Blavatskii (*KSIIMK*, 1959, pp. 174 ff.). G. P. Ivanova (*AP* XI, 1962, pp. 169–180) deals with stone stelae with a usually armed figure, or figures of raiders sculptured in relief on them. She points out that they were artless products of local monumental masons, mainly of the 2nd and 1st centuries B.C., seldom a work of a gifted sculptor-artist. She debates on their origin, aim and meaning. A similar study by the same author (*AK* XX, 1966, pp. 93–106) is devoted to the figure of Hermes sculptured in relief on stelae, to figures of this deity in Panticapaean tombs, and to marble figurines of Demeter and Kibela, found in various parts of the Bosporan Kingdom. The article by V. M. Brabich (*KSIAK* 9, 1959, pp. 90–92) devoted to the representations of griffins on Panticapaean coins of the 4th century B.C. onwards may also be mentioned. According to the author they may have been magical protective marks for the Bosporan wealth in crops and fishes.

B. I. Boltunova (*KSIAM* 116, 1969, pp. 49–54) published a number of hitherto unknown grave stelae from Panticapaeum of the period the 1st and 2nd centuries A.D., with sculptures in relief; and E. G. Kastanayan (*KSIAM* 116, 1965, pp. 45–48) devoted his attention to the wall-paintings in the Panticapaean dwelling houses, to their stucco works and to the reconstruction of their design of the 3rd to 1st centuries B.C.

Of importance is the article by I. T. Kruglikova (*KSIAK* 103, 1965, pp. 3–10)

who deliberates on the cause of the decline of the Bosporan Kingdom during the 3rd to 4th centuries A.D. She points out that a few Bosporan cities were destroyed before the Gothic invasion, in the first half of the 3rd century A.D., and that some retained their character as centres of industry and commerce over the 4th century, in spite of a rather adverse political development in the North Pontic area.

Finally, the study by K. V. Golenko (*ZOAO* I, 1960, pp. 334–339) is devoted to the latest Bosporan coins of Riskuporid VI (4th century A.D.).

Bosporan cities

A few volumes of *MIA* contain reports on excavations of several Bosporan cities. Thus *MIA* 85 (1958, 504 pages) in its 11 articles by 7 authors contains reports on the investigation of the towns of Ilurat, Tiritake, Mirmeki, Kimerikos, etc., and also an article by V. F. Gaydukevich (pp. 352–457) on Bosporan wine production. Volume, *MIA* 69 (1959, 323 pages) contains 7 reports by 8 authors of excavations of cemeteries of Nimphaea, Panticapaeum-Kerch, and of some other sites. Volume *MIA* 103 (1962, 260 pages) includes 14 articles by several authors on Panticapaean pottery, glass, metallurgy, and also descriptions of other remains excavated in Panticapeaeum up to 1953, and some even up to 1959. Volume *MIA* 56 (1957, 256 pages), includes 9 articles by 6 authors dealing with Panticapaean excavations during the period 1945–1953, and also during the campaign of 1934; in addition some problems relating to Panticapaean pottery, bone articles, handicrafts and commerce are discussed. Later excavations and special finds were reported by B. I. Boltunova (*SA* 1959 (1), pp. 168 ff.), V. V. Veselov (*SA* 1963 (2), pp. 233 ff.), N. I. Sokolskii (*KSIAM* 83, 1961, pp. 32 ff.), I. D. Marchenko (*AO* 1968, pp. 301–303; 1969, pp. 265 f.), and S. S. Bessonova (*SA* 1969 (1), pp. 137 ff.) reports on the excavation of the Panticapaean necropolis in 1963–1969.

According to L. I. Chuistova (*AP* XI, 1962, pp. 181–186), the epigraphic material from Panticapaeum-Kerch, and records of ancient authors imply the existence in the city of the worship of Aphrodite during the period from the mid-6th century B.C. to the 3rd century A.D. The author describes remains of foundations and walls at the site of the worship of that goddess.

Several Bosporan cities and smaller settlements were investigated in the Crimea besides those dealt with in publications quoted above; preliminary reports on the results obtained in most of these were published. In several cases excavations on a larger scale were conducted, e.g. on the site of the ancient city of Mirmeki, situated at the northern end of the Straits of Kerch. They were undertaken under the leadership of V. F. Gaydukevich in 1934–1938, 1946–1950, and in 1956 jointly with a Polish team. The results of these excavations were first briefly summarized by V. F. Gaydukievich and K. Michalowski in *AF* (1961, pp. 127–138), and then published in two special volumes both entitled *Mirmeki*, the first by K. Michalowski (in Polish, Warszawa 1958, 166 pages, supplemented by seven short studies on special items by seven authors), and the second volume by V. F. Gaydukiewicz (in Russian, Warszawa 1959, 124 pages) both volumes with summaries in French. The latter volume reports also on

the results of all former excavation campaigns. The results of subsequent investigations of the site were briefly summarized by V. G. Gaydukevicz (*KSAMO* for 1962, 1964, pp. 63–64; *AO* 1965, pp. 100–102; *KSIAM* 103, 1965, pp. 28–37) and by E. G. Kastanayan (*AO* 1966, pp. 232–225). V. I. Pruglo (*KSIAM* 116, 1969, pp. 29–35) describes and characterizes the stamps from Thasos of the 5th to 4th centuries found in Mirmeki. V. M. Brabich (*SA* 1963 (4), pp. 193–195) discusses a hoard of coins of the 3rd century B.C. found at Mirmeki.

A settlement surrounded by defensive constructions (earthwork) situated on the coast of the Sea of Azov, north of Mirmeki, ancient Pothmion, was investigated first in 1953, and again in 1968 by A. I. Boltunova (*AO* 1968, pp. 303 f.). The settlement was in existence from the end of the 6th to the early 3rd century B.C., when it was destroyed during the seizure of the Bosporan Kingdom by Mithridates VI Eupator. Near the southern end of the Straits of Kerch lay another important city, Nimphaion (Nimphea). The book *Iz Istorii Nimfeya* (*On the History of Nimphea*, Leningrad, Ermitage, 1962, 65 pages, 47 plates) by M. M. Khudiak, describes the history of the city during the period from the 6th to 3rd centuries B.C.; and a preliminary report on the excavation of the ruins of the city in 1958 was published by V. M. Skudnova (*KSIAM* 83, 1961, pp. 59 ff.), and then by N, L. Grach (*AO* 1966, pp. 218–220; 1967, pp. 222 f.; 1968, pp. 299 f.; 1969, pp. 273 f.; *KSIAM* 124, 1970, pp. 61–68). Excavation of the remains of the town of Ilurat was reported by I. G. Shurgaya (*AO* 1968, pp. 305 f.), by E. G. Kastanayan jointly with four other authors (*AO* 1966, pp. 223–225) and by M. M. Kublanov (*KSIAM* 128, 1971, pp. 78–85). A brief account on the results of the investigation during the 14 years 1947–1961 was given there by these authors, and further investigation in 1966 and in 1968 was reported by I. G. Shurgaya (*KSIAM* 124, 1970, pp. 61–69). A brief report on the excavation of the cemetery that belonged to the city has been published by M. M. Kublanov (*AO* 1969, pp. 258–260). Finally, the city of Kiteia, situated on the Black Sea coast, 40 km. west of Kerch, was investigated by N. S. Belova (*KSIAM* 83, 1961, pp. 83 ff.). Its lower layer was of the 2nd to 1st centuries B.C., and the upper one of the 5th century A.D.

A series of rural settlements all within the confines of the Bosporan Kingdom was investigated on the Peninsula of Kerch. Among these are three villages situated close to each other, Andreevka Iuzhnaya (5th to 3rd centuries B.C.), Andreevka Severnyaya (1st to 3rd centuries A.D.) and Novo-Otradnoe, formerly Adzhibay (3rd century B.C. to the 3rd century A.D.). The two former lay about 13–15 km. west of Kerch, the last one further north, on the coast of the Sea of Azov. Excavation of these was reported briefly by I. T. Kruglikova (*AO* 1965, pp. 110–113; 1966, pp. 220 f.; 1967, pp. 220 f.; 1968, pp. 307–309; 1969, pp. 116–117), and the last one, also by T. M. Arsenieva (*KSIAM* 86, 1961, pp. 66–69); recently the same author published a report on the excavation of a cemetery (*MIA* 155, *Poseleniya i Mogilniki Kerchenskogo Poliostrova Nachala N.E.—Settlements and Cemeteries of the Kerch Peninsula of the Beginning of Our Era*, pp. 82–149) which belonged to this settlement; there, at Novo-Otradnoe, emains of a Bosporan citadel situated close to the sea coast were uncovered within

the settlement; it was built with the settlement in the first century B.C., and was destroyed in the 3rd century A.D., at the time of the Gothic conquest of the Bosporan Kingdom. A large variety of beads found in burials of this cemetery have been described and classified by E. M. Alekseeva in the *MIA* 155 volume, mentioned above (pp. 150–169).

An important agricultural settlement, which at the same time was a fort (earthwork) with a citadel, built in about the 4th century B.C., was investigated at Mikhailovka, some 20 km. west of Kerch. It was destroyed in the 3rd century B.C., then rebuilt in the 1st century B.C., to be destroyed again in the 1st century A.D. The third phase of its existence lasted from the 2nd century A.D. when it was rebuilt, to the 3rd century A.D., when it was abandoned for good. Brief reports on its investigations were published by B. G. Peters, mainly jointly with G. M. Efimova (*AO* 1965, pp. 124–126; 1966, pp. 222 f.; 1967, pp. 224 f.; 1968, pp. 306 f.; 1969, pp. 268 f.; *KSIAM* 103, 1965, 119–127).

Preliminary reports on the excavation of two other settlements were published by I. T. Kruglikova (*KSIIMK* 78, 1960, pp. 64–73; *KSIAM* 83, 1961, pp. 73–83). In one of these, at Semenovka situated on the coast of the Sea of Azov, remains of huts with large earthen ovens or hearths, pottery, iron arrow-heads, fish-hooks, a figurine of a goddess, etc., were excavated, and also a score of Rhodian stamped amphorae of the 3rd and early 2nd centuries B.C. and Bosporan coins (the earliest of the 4th century B.C.), as reported by the same author (*KSIAM* 116, 1969, pp. 93–97). I. T. Kruglikova also published a report on the excavation of the cemetery at Semenovka (*SA* 1969 (1), pp. 98 ff.). Recently a full report on all investigations at Semenovka was published by I. T. Kruglikova (*MIA* 155, 1970, as quoted above, pp. 4–81), according to whom three occupation layers have been distinguished. The earliest one was of the 3rd to 2nd centuries B.C.; the second one embraces the 1st century B.C. and the 1st century A.D.; and the third one the late 3rd century A.D. The settlement was destroyed and abandoned at the turn of the 3rd and 4th centuries A.D. In the other settlement, at Geroevka, situated on the Black Sea coast, occupation layers have been uncovered of the period from the end of the 6th century B.C. to the turn of the Christian era.

The volume *Drevosti Vostochnogo Kryma—Predskifskii Period i Skifskii* (*Antiquities of the Eastern Crimea—Pre-Scythian Period and the Scythians*, Kiev 1970, 200 pages, editor A. M. Leskov) contains three articles devoted to the results of the excavation of a settlement of the Late Bronze Age and of the Pre-Scythian period at Kirovo, in the central part of the Kerch Peninsula, near the western border of the Bosporan Kingdom, the area later seized by the Bosporan kings. The first of the articles, by A. M. Leskov (pp. 7–59) is devoted to the description of the settlement; the next one, by D. V. Deopik (pp. 60–90) deals with the classification of the pottery of the settlement, and the third one, by V. I. Bibikova (pp. 97–112) specifies its faunal remains. Two subsequent articles, one by E. V. Yakovlenko (pp. 113–134), and the second one by the same author jointly with two others (pp. 136–179), contain the description of barrow-graves of rank-and-file Scythians excavated in six cemeteries

situated at Kirovo and five other sites north and north-west of that site; they were all of the period from the late 5th to the 3rd centuries B.C. The next article, by S. I. Zhilyaeva-Kruts (pp. 180–189) is devoted to the anthropological analysis of the cranial material from these cemeteries, but only 9 skulls out of 62 burials opened could have been classified.

The last article of the book by E. V. Chernenko (pp. 190–198) deals with the equipment of a Scythian warrior found in a burial at Nimphaea in 1868, consisting of a bronze helmet, bronze scale-armour with a decorative plaque in the shape of an elk-head, bronze shinguards and arrow-heads; all the articles are at present in the Ashmolean Museum, Oxford. The author points to their wrong classification in their former publications, and corrects the date of the burial which is the second half of the 5th century B.C., the period to which most burials belonged in the Nimphaean necropolis.

Two large barrows, called the Kara-Oba Kurgan and the Tsarskii (Royal) Kurgan, situated a few miles west of Kerch and already excavated in the XIXth century, were investigated again in 1965–1969; the aim was mainly to study their stone constructions. Around the first of these, formerly investigated in 1859, a double stone ring, 3 m. high, was uncovered under the mound. The only other finds were potsherds of the Hellenistic period excavated in the mound itself. Reports on these investigations were published by V. F. Gaydukevich (*AO* 1965, p. 102); by E. G. Kastanayan jointly with four other authors (*AO* 1966, pp. 223–225) and by P. N. Shults (*KSIAM* 28, 1971, pp. 55–65). E. V. Yakovlenko (*KSIAM* 124, 1970, pp. 54–60) described and published bronze bits, cheek-pieces and ornaments of Scythian bridles found in one of the Ak-Burun barrows in 1862. These articles of the 5th century B.C. have not been published hitherto.

Finally, the results of a survey of the country around Feodosiya (Theodosia) were briefly summarized by I. T. Kruglikova (*KSIIMK* 74, 1959, pp. 64–73).

The Taman Peninsula

The area on the other side of the Straits of Kerch, the Taman Peninsula and a strip of land along the Black Sea coast further south, were intensively investigated, and the reports published by several authors. Of importance are the results of a study by D. Ia. Berenbejn (*SA* 1959 (4), pp. 42–52) of the sea level in the Straits of Kerch. It was lower in antiquity, and accordingly, the straits were narrower than they are at present; they were only 1–2 m. deep and were subjected to freezing.

The chief ancient city excavated in that area was Phanagoria. The results of its earlier investigation have been published in *MIA* 57 (1956, 184 pages, 10 articles by 8 authors), and the architecture of the city, its wall paintings, terracotta figurines, and other articles, discussed. Brief preliminary reports on subsequent excavations were published by V. D. Blavatskii (*SA* 1961 (1), pp. 277 ff.); M. M. Kobylina (*SA* 1961 (4), pp. 271–274; 1963 (4), pp. 132 ff.; *AO* 1965, pp. 104–106; 1968, pp. 90–92; 1969, pp. 109–112; *KSIAM* 124, 1970, pp. 69–72); and by G. G. A. Tsvetaeva (*MIA* 130,

1965, pp. 234–235). The last author has shown that the destruction of Phanagoria's defensive wall in the 1st century B.C. was done by the Bosporan King Pharnaces, after the sack of the city in 47 B.C. In another article, the same author described remains of the defensive wall and of a few stone buildings of the 5th century B.C. (*KSIAM* 116, 1969, pp. 98–104). She also discusses the remains of wine factories and stores of the 2nd and early 3rd centuries A.D. uncovered in Phanagoria and points out that the wine industry and commerce of the city go back to the 4th century B.C. or even still further back.

A series of articles by M. M. Kobylina was devoted to some particular articles: to a sculptured portrait and marble statues and pedestals (*SA* 1962 (3), pp. 209–214) found in Phanagoria, mainly of the 5th to 4th centuries B.C., and she tries to identify the persons concerned. She also debates on the types of the images of Siren found in Phanagoria (*SA* 1967 (1), pp. 169 ff.) and on potteries of Phanagoria in the 4th century A.D. (*SA* 1966 (3), pp. 178–186). Examples of antique glyptography were dealt with by N. M. Nikulina (*SA* 1965 (2), pp. 185 ff.).

V. Blavatskii (*KSIIMK* 74, 1959, pp. 41–48) quotes 16 sites investigated during the period 1950–1954, settlements and cemeteries, including the city of Hermonassa, situated in the southern part of the peninsula. Excavations of Hermonassa were mainly conducted by I. B. Zeest who published several preliminary reports on these (*KSIIMK* 74, 1959, pp. 58–63; *KSIAM* 83, 1961, pp. 53 ff.; *AO* 1965, pp. 129–131; 1966, pp. 76 f.; 1967, pp. 84 f.; 1968, pp. 109–111; 1969, pp. 108 f.); and also N. P. Sorokina (*KSIAM* 83, 1961, pp. 46 ff.). N. I. Sokolskii (*KSIAM* 100, 1965, pp. 86–96) describes and classifies the 47 fragments of sculptures in relief and of grave stelae found in the foundations of the fortress of the 2nd to 1st centuries B.C. situated on the south-western coast of the Akhtanizovskii liman (Taman Peninsula). It was built by the Aspurgiani, a Sarmatian tribe who settled there. According to the author, the figures excavated represent the Sindians, the aboriginal people of the Taman Peninsula. The sculptures differ in many features from the Bosporan Greek sculptures. They were of the 4th to 1st centuries B.C., and the author emphasizes the important role of the Sindians in the development of the Bosporan art and in the political and economic life of the Bosporan kingdom of that period.

N. I. Sokolskii also published a series of brief preliminary reports on excavations at several sites within the peninsula; of a settlement of the 4th to 2nd centuries B.C. near Stanitsa Tamanskaya on the southern shore of the Taman Bay (*KSIIMK* 74, 1959, pp. 49–57); of the ancient fort of Patrey (1st to 4th centuries A.D.) (*AO* 1965, pp. 126–129; 1968, pp. 112 f.; 1969, pp. 188 f.); of the settlement at Ilikhovka, surrounded by defensive constructions, and of the earthwork of Kepy near Sennaya on the Taman Bay. The latter was a small Bosporan town founded in the 6th century B.C., and it existed up to the 10th to 12th centuries A.D. (*KSIIMK* 78, 1960, pp. 53–63; *KSIAM* 86, 1961, pp. 55–65; 83, 1961, pp. 66 ff.; 103, 1965, pp. 108–118; *AO* 1966, pp. 126–129; 1968, pp. 85–88). Its heyday was the 1st to 4th centuries A.D. N. I. Sokolskii also investigated a number of smaller settlements in that area (*KSIAM* 74,

1959, pp. 41–48), and a few cemeteries (*AO* 1968, pp. 88–90). A similar report published by A. K. Korovina (*AO* 1968, pp. 113 f.) is concerned with the excavation of the cemetery of the period from the 6th century B.C. to the 3rd century A.D. at ancient Tirambe, on the north-eastern limit of the peninsula, on the coast of the Sea of Azov. N. P. Sorokina published the results of the investigation of the cemetery at Tuzla, on the western end of the Taman Peninsula of the 6th to 5th centuries B.C. (*Trudy GIM* 26, Moscow 1957, 63 plus 24 pages); the report was reviewed by A. K. Korovina (*SA* 1959 (1), pp. 316–318).

Three articles by M. I. Maksimova are concerned with two richly furnished barrow graves opened at the turn of the present century. In two articles (*SA* 1960 (3), pp. 46–58; 1967 (2), pp. 240–242) she discusses the date of the Artiukhov barrow and fixes it at the time between 140 and 125 B.C. (E. H. Minns proposed the time around 200 B.C.). In the third article she deals with the so-called Akhtanizovskii hoard (*KSIAM* 116, 1969, pp. 35–58) which consists of silver vases and of richly decorated parts of horse harness. The articles originally belonged to the equipment of a very richly furnished burial which was destroyed by ploughing, and most of the equipment perished. The author tries to establish the whole list of its contents and dates the burial, as does K. F. Smirnov, at the end of the 2nd century B.C.

A few other Greek colonies, or settlements, lay already outside the Taman Peninsula. The north-westernmost of these were the remains of Gorgippia, present Anapa, the ancient capital city of the Sindians, where excavation began in 1959. The results of the subsequent excavation campaigns were briefly reported by I. T. Kruglikova (*AO* 1965, pp. 112 f.; 1966, pp. 75 ff.; 1967, pp. 82–84; 1968, pp. 115 f.; 1969, pp. 114–116; *KSIAM* 108, 1966, pp. 82–88). Two small contributions relating to a grave stella and to an agonistic catalogue found in that city were published by B. V. Lunin (*SA* 1963 (4), pp. 189–193) and by E. O. Berzin (*SA* 1961 (1), pp. 111 ff.).

South-east of the Taman Peninsula, close to the modern town of Novorossiisk lay a Bosporan stronghold, at present the earthwork of Rayevskoe. Brief reports of its investigation were published by V. D. Blavatskii and N. A. Onayko (*KSIIMK* 1959, pp. 42–61; *SA* 1967 (2), pp. 155 ff.; *KSIAM* 103, 1965, pp. 125–130) and by G. A. Tsvetaeva (*KSIAM* 116, 1969, pp. 105–110). The fort was built in the 4th to 3rd centuries B.C., and was several times rebuilt; it was in existence until the Middle Ages. It lay on the south-easternmost outskirts of the Bosporan kingdom, and it had chiefly a strategic—not an economic—importance. Its inhabitants were Greeks mixed with the Scytho-Maeotians at first, and with the Sarmatians later. A settlement of the 4th to 3rd centuries B.C. was investigated by N. A. Onayko (*AO* 1967, p. 82; *KSIAM* 128, 1971, pp. 73–77) at Shirokaya Balka near Novorossiisk, and another one in the same region, of the 1st to 4th centuries A.D., at Myskhako (*KSIAM* 124, pp. 73–80). At Khutor Rassvet near Anapa several small terracotta statuettes and figurines were found in the ruins of a larger building. They represent various Greek goddesses of the time between the 2nd century B.C. to the lst century A.D., and specify the cults current among the local people at that period, as reported by Iu. S. Krushkol

(*SA* 1971 (4), pp. 222–225).

Several sites and ancient settlements were recorded by N. A. Onayko during his survey of the Black Sea coast from Novorossiisk in the north to the region of Gelendzhik in the south (*AO* 1965, pp. 107 f.; 1966, p. 74; *SA* 1970 (1), p. 130 ff.). A similar survey of ancient sites of the same period, situated along the Black Sea coast between Gelendzhik and Sochi (250 km.) which all yielded Greek pottery, was undertaken by I. B. Brashinskii (*AO* 1965, pp. 113–115).

Tanais

Reports on excavations of the earthwork of Elizavetovskaya in the delta of the Don were quoted in *Bulletin* 10 (p. 126). Two articles were however omitted, those by B. V. Lunin and by S. M. Markov, which contain a brief history of all excavations of this earthwork since the XVIIIth century, and their results; they appeared in a small booklet *Arkeologicheskie Raskopki na Donu* (*Archaeological Excavations on the Don*, Rostov-on-Don 1962, pp. 5–22 and 23–39 respectively). A brief report on the recent excavation of the earthwork was published by I. B. Brashinskii (*AO* 1969, pp. 104 f.), and another one on the investigation of the cemetery that belonged to the earthwork by the same author jointly with A. I. Demchenko (*KSIAM* 116, 1969, pp. 111–117). Excavation of this cemetery in 1959 was previously reported by V. I. Shilov (*SA* 1961 (1), pp. 150 ff.), and a contribution may also be mentioned by I. B. Brashinskii (*SA* 1961 (3), pp. 178 ff.) who discussed amphorae and other finds from the end of the 4th century B.C. from the earthwork and barrow grave 8.

Other recent investigations of sites in the area on the lower Don have also been reported. The layer of the early centuries of the Christian era at the Kobiakovo earthwork was excavated, as reported by S. I. Kaposhina (*KSIAM* 103, 1965, pp. 45–52), jointly with the cemetery that belonged to it; the burials were mostly Sarmatian like the burials in barrows at Aksay, Novocherkassk and other sites excavated at the same time. In one of these, called Sadovii Kurgan, near Novocherkassk (*KSIAM* 116, 1969, pp. 76–79) a Celtic bronze cauldron was found of the period 1st to 3rd centuries A.D., which Kaposhina connects with the Galatians who might have served as mercenaries of Mithridates VI Eupator. V. E. Maksimenko (*AO* 1969, pp. 92 f.) reports on the excavation of two barrow graves; at Konstantinovka east of Rostov-on-Don, which contained 35 burials among which a few were of the Scytho-Sarmatian age; and Kurgan Radutka on the Koysug, a left tributary of the delta of the Don, 40 m. in diameter, in which a few secondary burials were of the Early Iron Age. The results of the excavation of the Maeotian cemetery near the town of Azov in the delta were the theme of the contribution by I. S. Kamenetskii (*SA* 1968 (2), pp. 264 ff.).

The most important site, at present an earthwork, at Nedvigovka, within the delta of the Don, was the fortified town–city of Tanais. It was built by the Bosporans in the 3rd century B.C. in the vicinity of the earthwork of Elizavetovskaya. It was in existence till the onslaught of the Huns in the 4th century A.D., when after its destruction it was abandoned entirely. A series of reports on the results of the excavation of

its ruins have been published: those of the campaign of 1955–1961 by D. B. Shelov in the booklet of 1962 (pp. 70–77) quoted in the preceding paragraph; in *KSIIMK* 74, 1959 (pp. 74–80), 77, 1959 (pp. 62–69); *KSIAM* 100, 1965 (pp. 79 ff.); 107, 1966 (pp. 92–97); *AO* 1965 (pp. 120–123), 1967 (pp. 91 ff.); by A. I. Boltunova in *AO* 1966 (pp. 83–85); and by T. M. Arsenieva in *AO* 1968 (pp. 116–118) and 1969 (pp. 105–107). The results of the excavation of the 'flat' cemetery of Tanais have been published by D. B. Shelov in *Nekropol Tanaisa* (*The Necropolis of Tanais*, *MIA* 98, 1961, 97 pages, 49 plates, 9 of these in colour). Most burials were of the period from the 3rd to 1st centuries B.C., and only a small number were of a later date, up to the time of the abandonment of the city in the 4th century A.D. The book contains a detailed description of all grave goods, of the burial ritual and of other aspects of the burial customs. The other cemetery of the city, consisted of barrow graves. Report on its investigation was published by L. M. Kazakova and I. S. Kamenetskii (*KSIAM* 124, 1970, pp. 81–87). Finally, according to A. B. Shelov (*KSIAM* 107, 1966, pp. 92–98) in 1962–63 the earthworks of Nizhne-Gnilovskoe and of Podazovskoe were investigated, both of the 1st and 2nd centuries A.D.

A series of publications bear a more general character. Here belongs a pamphlet by D. B. Shelov, *Drevnii Gorod Tanais* (*Ancient City of Tanais*, Odessa 1961, 36 pages) which contains a brief description of the city in the light of the archaeological material excavated there and of the city's cemetery at the time of this publication. A similar review of the city in the 3rd to 2nd centuries B.C., as reflected in the archaeological material, was the theme of an article by A. I. Boltunova in the booklet of 1962 (pp. 78–94) quoted at the beginning of this Section. The book (paperback) *Drevosti Nizhnego Dona* (*Antiquities of the Lower Don*, *MIA* 127, 1965, 263 pages, editor D. B. Shelov) contains 8 articles by 7 authors, including reports on excavations at Tanais in 1955–1961. M. M. Gerasimov gives in his article an anthropological consideration of the osseous material from the 'flat' cemetery of Tanais. Bones were in bad state of preservation but in spite of that the author established that two different types could be distinguished there; the Sarmatian type and the other of the aboriginal population, probably Maatieon. A few skulls were deformed and had some mongoloid features. Another book, *Antichnye Drevnosti Podonya-Priazovia* (*Ancient Antiquities of the Country on the Don and the Sea of Azov*, *MIA* 154, 1969, 288 pages, a paperback) also contains 8 articles by 7 authors, either reports on the results of current excavations in various parts of the city of Tanais, or descriptions of some remains found in that site, or discussion of some special problems connected with the activities of the city. The article by D. B. Shelov in *MIA* 130 (1965, *Novoe v Sovetskoy Arkheologii*, pp. 229–234) is devoted to the 'Pintaderas', clay stamps, found in the layers of the 1st to 3rd centuries A.D. of Tanais.

Special mention deserves to be made of the fine, recently published, well produced book by the above author, D. B. Shelov, *Tanais i Nizhnii Don v III–I vv.do n.e.* (*Tanais and the Lower Don in the III–I centuries A.D.*, Moscow 1970, 252 pages several unnumbered illustrations in the text and plans of the areas excavated). Recently its

enlarged edition appeared under a slightly modified title, *Tanais i Nizhnii Don v Pervye Veka Nashei Ery* (*Tanais and the Lower Don in the First Centuries of our Era*, Moscow 1972, 352 pages). Thoroughly discussed are the preconditions of the foundation of the city-colony of Tanais by the Bosporans; the city's history and its role during the first period of its existence, up to the turn of the Christian era is reconstructed; archaeological remains excavated at the site up to that time have also been described. Special chapters are devoted to the discussion of the economic and political conditions of the city during the first period of its existence, and also the reasons for its destruction at the end of the pre-Christian era by the Bosporan King Polemon. The book is provided with indexes, which is a very rare but welcomed exception in archaeological books published in the USSR. This theme has been already previously discussed by this author (*KSIAM* 116, 1969, pp. 70–79).

A brief note by E. A. Tsepkin (*KSIAM* 124, 1970, pp. 115–117), also deserves mention as this gives statistical data on the kind of fishes caught by the city's fishers for the market, as indicated by their bones found in kitchen refuse and stores, and also for export to the south. It may also be mentioned that fishing by the inhabitants of the Don earthwork in the early mediaeval period was the theme of the article by B. A. Shramko and E. A. Tsepkin (*SA* 1963 (2), pp. 74 ff.).

E. M. Alekseeva and T. M. Arsenieva (*SA* 1966 (2), pp. 176–188) describe the remains of a glasswork destroyed during the destruction of Tanais around A.D. 240 to 250, and describe the types of vessels, plain or decorated beakers, bowls, phialae, jugs, beads, etc., produced there during the 2nd and first half of the 3rd centuries A.D. The glass produced was of West European type, yellow or greenish in colour and very similar to that produced in the Crimean Alma-Kermen glasswork.

Finally, two articles concerned with the so-called Fedulovskii hoard may be mentioned. In the first of these, I. P. Zasetskaya (*ASE* 7, 1965, pp. 28–36) briefly gives the history of this find at Khutor-Fedulova near Bagaevskaya (close to Rostov-on-Don) on the southern side of the Don, and describes the silver phalerae and the few golden ornaments, including a horse 'swastika', which form this hoard and deliberates on the purpose of all the articles which belonged to the very rich set of horse harness. She concludes that the find belonged to the Sarmatian culture and dates it as the 3rd century B.C. The same date has been proposed by I. Berchin (*Soobshcheniya Gos. Ermitazha* XXII, 1962, pp. 27–39) who considers all articles of the hoard to have been the work of Bosporan silver and goldsmiths of the end of the 3rd century B.C. Of a later date, of the 2nd to 1st centuries B.C., is a similar find from Ianchokrak on the Konka in the *oblast* of Zaporozhe in the southern Ukraine, dealt with in a special article by I. I. Gushchina (in *Drevnosti Vostochoy Evropy*, *MIA* 169, 1969, pp. 43–51). She considers it to have belonged to a member of the Sarmatian aristocracy who in the 3rd to 2nd centuries B.C. advanced into the Ukraine, as did a number of hoards of the same type found in the Pontic steppes. She also points out that the further to the west the relative find was discovered, the later is its date.

The Sarmatians

During the Early Scythian period, the 6th to 5th centuries B.C., the steppe east and south of the lower Volga and the Don, up to the Caucasus, was in the possession of the early Sarmatians, the Sauromatians of Herodotus. Accordingly, the name of the Sauromatian culture has been given in the archaeological literature to the remains attributable to these early Sarmatians, and the period has been called the Sauromatian period. Remains of the subsequent period, the Early Sarmatian period, the 4th and 3rd centuries B.C. have been called of the Prokhorovka type, or culture, after a site in the region of Orenburg in South Urals. They differ in several respects from those of their preceding Sauromatian remains. They exhibit many Central Asiatic elements undoubtedly introduced by some Asiatic Sarmatian tribes who invaded the country and forced a large part of the Sauromatians to retreat westwards into the country held by the Scythians.

The literature concerned with the whole early Sarmatian period and the area of settlement of the Sarmatians of that time is very huge. All larger publications and a great many of articles dealing with topics connected with these have been quoted in my book *The Sarmatians* (London 1970, Thames and Hudson; Ancient Peoples and Places Series, 267 pages, 75 maps and illustrations, and 60 half-tone illustrations). The most important of these are the books by K. F. Smirnov: *Savromaty. Rannaya Istoriya i Kultura Sarmatov* (*Sauromatians. Early History and Culture of the Sarmatians*, Moscow 1964, 380 pages, 48 full page illustrations); and his *Vooruzhenie Savromatov* (*The Sauromatian Armature*, Moscow 1961, *MIA* 101, 170 pages, 58 full-page illustrations and 5 folded tables); and also K. F. Smirnov and V. G. Petrenko, *Savromaty Povolzhiya i Iuzhnogo Priuralia* (*Sauromatians of the Country on the Volga and of South Urals*, Moscow 1963, *SVOD* D-1-9, 40 pages, 30 plates). The articles by K. F. Smirnov should be mentioned here, one on the production and the character of the economy of the Early Sarmatians (*SA* 1964 (3), pp. 45–63), and another one (in French), on the distribution of Sarmatian tribes in Eastern Europe (*Rapports* USSR VI Prehistoric Congress, Moscow 1962). Other important publications are *Pamyatniki Epokhi Bronzy i Zheleza v Severnom Prichernomorie* (*Remains of the Bronze and Iron Ages in the North Pontic Country*, *MIA* 96, 1961) in particular its article by V. G. Petrenko (pp. 52–102), already mentioned in *Bulletin* 10 (p. 121), which exhibits several Sauromatian elements in the Late Scythian culture of the country west of the Dnieper. Another one is *Pamyatniki Skifo-Sarmatskoy Kultury* (*Remains of the Scytho-Sarmatian Culture*, *MIA* 115, 1962, 287 pages) in particular its articles by M. G. Moshkova, M. Kh. Sadykova and M. P. Abramova, dealing with Sarmatian remains—and remains which bear evident traces of Sarmatian influence—in the region of Orsk in the South Urals, in Bashkiria, and also on the lower Dnieper. And finally, the issue of *SVOD* D-1-10, *Pamyatniki Prokhorovskoy Kultury* (*Remains of the Prokhorovka Culture*, 1963, 56 pages, 32 plates two of them coloured) by M. G. Moshkova on the Early Sarmatian culture of the 4th to 3rd centuries B.C. The article by M. P. Abramova (*SA* 1959 (1), pp. 52–71) deserves mention, too. It deals with the

subsequent, Middle Sarmatian period of the 2nd century B.C. to the 1st century A.D., characteristic of which was the Suslov culture.

Several smaller contributions that appeared during the period under review deal with some special aspects of the Sarmatian culture, or with some specific item characteristic of that people. Thus M. P. Abramova (*SA* 1969 (2), pp. 69 ff.) is concerned with Sarmatian pottery with zoomorphic handles. A. M. Khazarow, in the first of his three articles (*SA* 1963 (4), pp. 58–71) discusses the history of Sarmatian bronze mirrors; he is of the opinion that they developed locally under Scytho-Siberian influence mainly in the Christian era, and that the Greek influence was only of little importance. His second article (*SA* 1969 (2), pp. 169 ff.) is devoted to Sarmatian swords with a ring-shaped pommel; and in the third one the author (*SA* 1970 (2), pp. 273 ff.) deliberates on some topics connected with the origin of composite bows. The latter theme, concerning in fact the culture of the Sarmatian–Alan tribes when still in Asia, was dealt with by B. A. Litvinskii (*SA* 1966 (4), pp. 51–67).

P. M. Kozhin (in *Drevnosti Vostochnoy Evropy*, *MIA* 169, 1969, pp. 92–95) deliberates on Sarmatian vehicles. He is of the opinion that they were of a considerable value in the steppes, and have therefore seldom been deposited in graves. In the Sarmatian culture in the steppe on the lower Volga and in the South Urals area, they were found exclusively in graves of persons of a very high social position. They came down to us very incomplete, as probably only some parts of the vehicle were offered to the dead chief; their reconstruction is therefore not practicable. In this context two important articles by K. F. Smirnov may be mentioned. One of these is devoted to the earliest horsemanship in the Volga–Urals steppes. The author pays special attention to the earliest bone cheek-pieces from the middle and the second part of the second millennium B.C. and early first millennium B.C. All specimens found in Eastern Europe have been listed and classified according to the types established by Potratz, their parallels in Central Europe and in the Mediterranean countries quoted, and their development up to the Early Scythian period followed. It may also be mentioned that the list of early cheek-pieces found in Eastern Europe was later supplemented by A. M. Leskov (*SA* 1964 (1), pp. 299–303). The other, an earlier, article by K. F. Smirnov (*SA* XXVII, 1957, pp. 209–221) deals with horse burials of the Srubnaya culture of the Bronze Age (the second half of the second millennium and early first millennium B.C.) in the steppe on the lower Volga, which were the earliest ones of this type in Eastern Europe. The practice was later taken over by the Sauromatian culture. The author also discusses some problems involved in these burials.

Of particular interest is the report by K. F. Smirnov and S. A. Popov (*MIA* 169, 1969, pp. 210–216, with a folded plan; *AO* 1967, pp. 113 f.). In 1966–1967 17 barrow graves of the Srubnaya and Sarmatian cultures were excavated in the region of Buzuluk, between the villages of Lipovka and Proskurino. The bulk were of the Sauromatian period, many were looted. One of the mounds, situated on the periphery of the barrow-grave cemetery, was 20 m. in diameter and was surrounded by a dyke. The encircled area was covered with a layer, 2 to 15 cm. thick, of soot, cinders and

pieces of charcoal, and in several places traces of small hearths were spotted. The construction was evidently a fire-worship site, a kind of shrine. A similar 'shrine' was also found under one of the mounds of the barrow-grave cemetery of the Sarmatian culture at Alandskoe in the region of Orsk.

Sauromatian–Sarmatian burials

Three quite recently investigated Sarmatian graves are of special importance. One of these was burial 2 in barrow 5 at Verkhnee Pogromnoe on the lower Volga in the region of Volgograd, investigated by V. P. Shilov. A gold spiral armlet with zoomorphic terminals was found there together with a gold plaque representing a doe attacked by two rapacious beasts. Two similar spiral gold armlets were excavated in the female burial 8 in barrow 55 at Kalinovka in the same region, like the other burial richly equipped in gold personal ornaments (V. P. Shilov, *MIA* 60, 1959, pp. 402 ff., fig. 51 coloured). Both burials were of the Middle Sarmatian period, of the 1st century B.C. to the 1st century A.D., and are attributable to the ancient Aorsi (see my *The Sarmatians*, pls 23, 32 and 25, 26). The articles above evidently lower the date of several similar items of the famous Collection of Siberian personal ornaments of Peter the Great, at present at the Hermitage Museum in Leningrad, although the corresponding Siberian specimens must have been of a somewhat earlier date (preceding the western drive of the Siberian Sarmatian tribes) of the Early Sarmatian period, the 4th to 3rd centuries B.C.

The third one is the richly furnished female princely burial of the 5th century B.C. at Sazonkin Bugor (Sauromatian), published by I. P. Berkhin-Zasetskaya and L. Ia. Malovitskaya (*SA* 1965 (3), pp. 143–153). A pair of almost identical gold temple ornaments of a special shape are the most striking item of its grave goods. They are made of a thin gold wire each in the shape of a pair of horses standing on a four-wheeled platform (chariot?) lead by a rider. Pendants very similar to these, made in the same technique, have been found in Transcaucasia (see my *The Sarmatians*, pl. 6). They point to the origin of the specimens found in the Sauromatian burial on the Volga.

On the other hand, the Sarmatians must have been in close contact with their kindred peoples east of the Urals and the Caspian Sea. A. N. Melentiev (*AO* 1968, pp. 147–149) reports that in two points in the neighbourhood of Karauzek, the lake Ata-Kul and in the region of the Ryn-Peski desert near Astrakhan, pottery was found closely related to that of the Karasuk culture of the Yenissey valley, and also to that of the Tagisken (ancient Chorasmia) type. A vessel made on the potters-wheel, evidently imported from Chorasmia (south of the Sea of Aral) was found in a female burial of the Sarmatian culture in the region of Troitskoe north of Buzuluk as reported by S. A. Popov (*AO* 1968, pp. 144 f.). In another female grave of the same barrow-grave cemetery a pendant-amulet of blue matter with an image of a resting lion was found.

Several brief reports on the excavation of Sarmatian barrow graves of various

periods have been published. A short survey of investigations within the area on the lower Volga, especially within the territory of the Stalingrad hydroelectric establishment has been published by N. Ia. Merpert and K. F. Smirnov (*KSIAM* 84, 1961, pp. 7 ff.), and V. I. Mamontov in his three articles gives the description of a number of Sarmatian barrow graves excavated at Korolevskoe (district of Novo-Annenskii, *AO* 1969, pp. 155 f.), and at Zakanalny cemetery (*AO* 1968, pp. 127 f.) where in a looted grave among other things were found a bronze cauldron of the 1st century A.D., and several small gold plates decorated with images of griffins, evidently originating from North Pontic workshops. A few barrow graves were investigated in the southern outskirts of Volgograd (*AO* 1967, pp. 110 f.), some of which yielded Sarmatian, mainly Middle Sarmatian, burials. A Sarmatian bronze cauldron, a variety of beads and other ornaments and small gold plates were found there. Excavation of barrow graves of the Sarmatian Age at Novyi Aksay, between the Volga and the Don was reported by V. P. Shilov (*AO* 1966, pp. 87–89). A Sarmatian grave in the delta of the Don was described by V. E. Maksimenko (*SA* 1970 (2), p. 224 ff.), and A. N. Melentiev (*AO* 1967, pp. 111–113) mentions a newly discovered Sarmatian cemetery of the period 4th to 3rd centuries B.C. at Karauzek, and another one of the 6th to 5th centuries B.C. at Istay-Babay, both situated on the watershed between the Volga and the Ural river.

Several Sarmatian cemeteries and burials have also been discovered further north in the steppe of the lower Volga in the region of Saratov, and also in the South Urals further to the north (up to Bashkiria), and further to the east. I. V. Sinitsyn investigated a large cemetery (about 100 mounds) at Rovnoe in the region of Saratov, among which several were Sauromatian or Sarmatian of the period from the 6th century B.C. to the 3rd century A.D. According to E. K. Maksimov (*AO* 1968, pp. 154–156) 29 barrows were excavated at Novo-Lipovka district of Sovetskii near Saratov. Thirty-two Sarmatian burials were found in these, 15 of which were of the 'diagonal' type. They were better equipped than other burials and furthermore, their equipment differed to some extent from that of the rest. The people buried in these graves evidently belonged to a different social but also ethnic group. The same author also reports (*AO* 1969, pp. 147 f.) on the excavation of 12 barrows at Krutoyarovka on the Bolshyi Karaman, in the same region as those above. They yielded 25 Sarmatian burials a few of which were of the Sauromatian period; the bulk were of the period from the 1st century B.C. to the 1st century A.D., and the latest ones were of the 2nd to 3rd centuries A.D. Articles found in all these burials have been briefly described.

One of the most richly equipped graves in this area was the female burial in barrow 96 at Bolshaya Dmitrievka on the Karamysh river, excavated in 1887. It belonged to a cemetery consisting of over 100 mounds. The description of the burial and its equipment was published by E. K. Maksimov (*SA* 1957 (4), pp. 157–161). Among items of its equipment are a bronze Roman period bowl, a bronze dipper with a long handle, a ring and another crenated ring, a bronze figurine of a camel, a paste bead and a number of clay vessels. The burial was of the end of the Middle

Sarmatian period, approximately the turn of the 1st and 2nd centuries A.D.

Investigation of Sarmatian burials at Lyubimovka on the river Buzuluk, a tributary of the Samara on the northern periphery of the proper Sarmatian territory, was undertaken as early as 1896 (K. F. Smirnov, *KSIAM* 89, 1962, pp. 83–93). In 1962 one barrow was excavated in which an original Sauromatian burial and four secondary burials were found, the latter all of the Early Sarmatian, Prokhorovka culture, of the 3rd to 2nd centuries B.C.

Excavations on a larger scale were conducted in the region of Orsk mainly at Alandskoe, and also in its neighbourhood. Thus M. G. Moshkova (*KSIAM* 83, 1961, pp. 115–125) reports on the investigation of barrows at Alandskoe and Novo-Kumak; five were early Sarmatian, of the 4th to 2nd centuries B.C. (the Prokhorovka culture). In two later reports (*AO* 1965, pp. 97–99; 1966, pp. 114–116), M. G. Moshkova and K. F. Smirnov give account of the excavation of the Alandskoe barrow graves, and of the cemetery and a Bronze Age settlement on the Karabutak river. Ten mounds were investigated in which 24 Sarmatian (mainly Sauromatian) burials were uncovered. Sauromatian burials were mostly ransacked, but one, a grave of a priestess of the 5th to 4th centuries B.C., was of particular interest. Among its equipment were a three-footed stone 'altar', a bronze mirror and glass beads. Contiguous to this barrow was another one with a male burial. Both burials were of the 'diagonal' type. In the area between the two burials, on the ancient ground level, lay a small heap of animal bones mixed with human ones. Three loose human skulls were also found there. A summary of his results of the investigation of 25 barrows near Khutor Baryshnikovii and Gerasimovka on the Ilek south of Orenburg, was given by K. F. Smirnov (*KSIAM* 107, 1966, pp. 33–43). One hundred and forty-four burials were uncovered in these mounds, 24 of which were Sarmatian. They were all secondary burials except a single burial which was the primary one. All details regarding the type of burials, their equipment, date, etc. have been tabulated in a graph. A score of barrow graves of the Bronze Age Andronovo culture were excavated by V. S. Sorokin (*KSIAM* 71, 1958, pp. 78–85) at Ak-Zhar and Ulke in the area south of the Urals, west of the river Emba, which forms part of West Kazakhstan. Several secondary burials were found in these, among them a few Sauromatian of the 6th to 4th centuries B.C., some Sarmatian of the 3rd to 1st centuries B.C., and also of the period from the 2nd to the 4th centuries A.D.

Sarmatian remains outside their original country

The results of the investigation of archaeological remains of the period under review, undertaken in the region of Cheliablinsk, already in the forest-steppe zone north of the Sarmatian held steppe, have been published by M. G. Moshkova (*MIA* 169, 1969, pp. 138–147). She distinguishes two coeval but different types of remains in that country. One of these is barrow graves of the intrusive Sauromatian culture, and the other the remains of the ancient local population of Ugro-Finnish stock and of Neolithic ancestry. The impact of the intrusive culture which spread over the country in the 7th(?) and 6th century B.C., has been explained as has its progress.

During the 4th century B.C. a revival of ancient local traditions took place which resulted in the formation of several local hybrid groups. Similar results from the study by K. V. Salnikov (*SA* 1958 (4), pp. 23 ff.) were published several years ago, showing the relations between the local Ugro-Finnish settled population of the country and the Sarmatians, who greatly contributed to the formation, by the turn of the Christian era, of a new hybrid culture. Early Sarmatian burials have also been found west of the above area in Bashkiria. A. Kh. Pshenichniuk (*AO* 1968, pp. 141 f.) reports on the excavation of Sarmatian barrow graves in the region of Karmaskaly, south of Ufa, and of Sterlitamak and Kumertau. All burials were very poorly equipped, and a few, probably originally better furnished, were ransacked. The same author (*AO* 1969, pp. 159 f.) also reports on the investigation of a number of Late Sarmatian burials in the region of Miyaki in south-west Bashkiria.

The local non-Sarmatian peoples of the forest-steppe and forest zones of Eastern Europe of the period under review will be dealt with in the subsequent section.

Early Scythian daggers of the Akinakes type found west of the Volga, in the province of Penza, have been dealt with by E. K. Maksimov and M. P. Polesskikh (*SA* 1971 (2), pp. 238–242). Similar specimens found in Scythia and the Sarmatian territory and in other areas have been quoted and dated. Those from Penza are of the 6th century B.C. South of Penza, in the region of Nechaevo on the Tishanka, a tributary of the Khoper, 15 barrow graves were investigated, as reported by A. S. Skripkin and N. S. Chernyshev (*AO* 1969, pp. 145 f.). The barrows were mostly of the Bronze Age (Catacomb and Srubnaya cultures) but several Sarmatian secondary burials were found in their mounds. A few mounds were raised over Sarmatian graves. Caucasian and Bosporan imported and local pottery, brooches, beads, iron arrow-heads, etc. were found in graves; they point to the date being the early centuries A.D.

Sarmatian remains found within the North Caucasian foothills of the period from the 3rd century B.C. to the 1st century A.D., have been expounded by V. B. Vinogradov (*SA* 1968 (1), pp. 48 ff.), and the same author has also paid attention to the Siracians in the North Caucasus (*SA* 1965 (1), pp. 108 ff.). V. B. Vinogradov (*SA* 1960 (3), pp. 309 f.) also described Egyptian faience scarabs and beads of the turn of the Christian era found in the region of Groznyi in the north-east Caucasus. The book by this author, *Sarmaty Severo-Vostochnogo Kavkaza* (*Sarmatians of the North-East Caucasus*, Groznyi 1963, 178 pages, 48 plates) was not available in London. Its review by V. A. Kuznetsov and B. N. Grakov appeared in *SA* (1964 (4), pp. 232–237; 237–240). M. P. Abramova (*SA* 1968 (3), pp. 114–130) describes newly discovered Sarmatian graves in Kabardino-Balkaria in the North-West Caucasus, and M. N. Pogrebova discusses the iron battle-axes of Scythian type found in Transcaucasia (*SA* 1969 (2), pp. 179 ff.).

Sarmatian remains in the Crimea have been mostly treated jointly with those of the Crimean Scythians and the Bosporan Kingdom. A special article by I. I. Gushchina (*SA* 1967 (1), pp. 40 ff.) has however been devoted to the Sarmatians in the Crimea. In another article N. A. Bogdanova (*SA* 1965 (3), pp. 233–237) discusses and pub-

lishes Scythian and Sarmatian stelae found in the cemetery at Zavetnoe near Bakhchyseray. They were of the 1st century B.C. to the 3rd century A.D.

The westwards migration of Sarmatian tribes undertaken under the pressure of their kindred eastern neighbours, is well marked by Sarmatian remains of the subsequent periods found in the Ukraine. Their earliest traces, in fact of the 'Sauromatians', form part of the Late Scythian culture (see my former report in *Bulletin* 10, pp. 102 f.). But also typical Sauromatian graves were found in the Ukraine which well attest to the influx of eastern elements into the steppe on the lower Dnieper. One of such graves was discovered at Ushkalka (D. Ia. Telegin, *KSIAK* 8, 1956, p. 48 ff.) in which alongside Scythian bronze arrow heads a vessel was found with a rounded base, typical of the Sauromatian culture of the Southern Urals. Another grave characteristic of the Sauromatian culture was discovered at Hrushivka in the same region on the lower Dnieper (D. T. Berezovets, *AP* X, 1961, p. 59, fig. 4). According to the report by E. V. Makhno (*AP* IX, 1960, pp. 24–31), a Sarmatian barrow grave cemetery of a later period, of the time from the 2nd century B.C. onwards to the Late Sarmatian period, was investigated at Ust-Kamyanky, at the junction of the Kamyanka and Bazavluk rivers, west of Nikopol. In 20 mounds 24 primary and 7 secondary Sarmatian burials were uncovered.

The literature relating to the archaeological remains of the two last centuries B.C., attributable to the Suslov culture, to the Roxolani, the Crimean Scythian kingdom, etc., will be dealt with in my next report.

The forest zone

A few publications relating to the area have a more general character. One of these (*MIA* 61, 1958, pp. 221–281), mentioned already in my present report (p. 3), contains the study by V. I. Tsalkin of the fauna of the area during the period under review based on the excavated osseous material. Another volume of *MIA* (58, 1957, pp. 5–113) contains the work by A. P. Smirnov on the Iron Age of Bashkiria, the country on the western side of the South Urals. The prehistoric past of that country, from the Neolithic to the 7th century A.D., has been dealt with in the paperback *Drevnosti Bashkirii* (*Antiquities of Bashkiria*, Moscow, 1970 196 pages, 5 articles by 6 authors; editor: A. P. Smirnov). The second chapter of the article by E. I. Goriunova, *Etnicheskaya Istoria Volgo-Okskogo Mezhdurechiya* (*Ethnic History of the Country between the Rivers Volga and Oka*, *MIA* 94, 1961, pp. 22–37) deals with the Iron Age of the area. There is discussion of the connections with the Ananino, Gladenovo, and Pianobor cultures, the formation of the Meria and Lomovatovskaya cultures and similar topics. Yet another article by V. A. Oborin (*MIA* 169, 1969, pp. 156–167) discusses the cultural links of the upper Kama tribes with those of North-Eastern Europe during the Iron Age. Over 300 new sites have been recently recorded in that area which embraces the country of Komi and the northern part of the *oblast* (province) of Perm. The study of the archaeological material implies strong ties of the local tribes with the Ananino culture on the upper Kama and its successive cultures,

and also with the neighbouring peoples to the west and east. The Iron Age of the country on the Vychegda, situated north-west of the country of Komi, was dealt with in a special chapter of the paperback by G. M. Burov, *Vychegodskii Kray* (*The Country on the Vychegda*, Moscow 1965, 198 pages). The Iron Age has been divided into three periods, the earliest of which is supposed—evidently wrongly—to have lasted from the 8th to the 3rd century B.C. In Transcaucasia, the country bordering on that in which iron first came into use, iron was introduced only in the 7th century B.C. (see p. 10).

According to R. B. Akhmerov (*SA* 1959 (1), pp. 156–167), at Ufa a new ancient cemetery has been discovered in 1952; its graves were of the time from the mid-first millennium B.C. to approximately mid-first millennium A.D. Graves were of two periods, the earlier ones of the Ananino culture, the later ones mainly of the 4th to 7th centuries A.D. In a burial of the 4th to 3rd centuries B.C. an iron sword and iron three-bladed arrow-heads of the Prokhorovka-Sarmatian type were found. At Shipovo, 30 km south of Ufa, on the Belaya 7 barrows of an ancient cemetery were excavated in which 25 burials were uncovered of the 4th to 3rd centuties B.C. They belonged to the Kaza-Abazskaya culture, to which also graves of the same cemetery belonged which had no mounds raised over them, as reported by A. Kh. Pshenichniuk (*AO* 1967, pp. 107 f.). Investigation of a flat cemetery of the Ananino culture of the 6th to 4th centuries B.C. in the northern part of Bashkiria at Tash-Elga on the Buy has been reported by N. A. Mazhitov (*AO* 1967, pp. 108–110).

A few smaller articles contain reports on investigations in various sites of the Iron Age situated further to the north. Thus O. N. Bahder (*KSIAM* 85, 1961, pp. 73–84) reports on the survey of the valley of the Kama south of the town of Perm. Within that region 7 settlements were recorded either entirely of the Ananino culture of the Early Iron Age, or at least with one of the occupation layers with remains of that culture. There were also 3 earthworks, all with several occupation layers one of these of the Ananino culture. Among the most important are the stratified settlement Zaiurchimskoe with occupation layers of various periods from the Neolithic up to the Ananino culture and the Bolshe Nikolskoe and Subbotinskoe earthworks. A. Kh. Khalikov (*AO* 1967, pp. 100–104) gives, jointly with three associates, a brief account of the excavation of the earthwork Gremyachii Kliuch situated on the right bank of the Kama. It was of the 6th century B.C. Investigation revealed that the area was very thinly populated during the late Ananino period, till about the 2nd to 3rd centuries A.D., when new colonists of the late Pianobor culture arrived there. Another earthwork, on the Ocher west of the Kama called Goriuchalichinskoe, was typical of the Gladenovskaya culture of the 2nd century B.C. to the 3rd century A.D., and was very similar to the Gremyachii earthwork mentioned above and several others. Articles found there have been briefly described and the author, Iu. A. Polyakov (*AO* 1967, pp. 125 f.) concludes that this must have been a local cultural and industrial centre which also served as a refuge for the population of the country around. It was constructed in the Ananino period and abandoned at the beginning of the Lomovatovskii period.

V. F. Gening and V. V. Odintsov (*AO* 1968, pp. 157 f.) describe the cemetery Nyrgynda II in the district of Karamulinskii, 88 burials of which were excavated in 1954 and recently. Only a few burials were well equipped and in many no grave goods have been found. In one male burial an iron sword was found and in another one iron bit. The cemetery was of the middle Pianobor period, although a few graves were late Pianobor. In the neighbouring village, some 500 m. from the above cemetery, at Dubrovka, a late Pianobor cemetery was discovered.

Finally, reports may be mentioned relating to the recent investigations of the cemetery of the Akhmylovo complex, which has already been dealt with by me in *Bulletin* 8–9 (p. 139). The reports are by V. S. Patrushev and A. Kh. Khalikov (*AO* 1967, pp. 124 f.) and by G. A. Arkhipov and his three associates (*AO* 1968, pp. 159 f.). The cemetery is one of the largest of the Early Iron Age within the whole area. Its date is from the 8th to the 5th centuries B.C., and it is attributable to the Ananino culture, although it differs in some respects from the typical cemeteries of the culture in the country on the middle Volga. The study of the grave-goods, and other features of the culture represented by the cemetery, inclines the authors to attribute these remains to ancient Finno-Ugrian tribes. Recently V. S. Patrushev (*KSIAM* 128, 1971, pp. 37–43) published a study devoted to the bronze 'celts' found in the cemetery of Akhmulovo.

Of interest is the grave of a shaman discovered in the cemetery of Koshibeevskii south-east of Riazan, reported by B. V. Trubnikova (*SA* 1969 (3), pp. 42–52) who also discusses the beliefs of the people (of the late Gorodetskaya culture).

An Experiment in the Mathematical Reconstruction of the Pottery from a Romano-British Kiln Site at Highgate Wood, London

by C. R. ORTON

1. *Introduction*

The Romano-British kiln site at Highgate Wood, London, which lies about five miles NNW of the Roman city of London, was discovered in 1962 during an archaeological field survey of the open spaces of north London. Excavation commenced in 1966 and has continued to date.[1] A number of kilns and a large quantity of pottery have been discovered, much of the pottery being wasters from the kilns themselves.

The pottery found was generally in a very fragmentary state, less than 1% of the vessels represented having a complete, or substantially complete, profile. Work on the pottery was therefore initially concentrated on devising a system of classification for the rim and base sherds.[2] In this system sherds are classified by a letter (A = rim, B = base) and a number, representing a category of rim or base. There were six categories of rim and three of base. Their definitions are given below:

A1: straight or curved rims, with no shoulder, neck or lip.
A2: horizontal rims with groove for a lid: no shoulder, neck or lip.
A3: as A2 but with no groove.
A4: everted rims with shoulder, neck and lip.[3]
A6: as A4 but with no lip.
A7: everted rims with shoulder but no neck or lip.
B1: bases with convex profile.
B2: bases with concavity in the profile.
B3: bases with a foot-ring.

A number of categories of decoration was also devised, but as they are not used in this report they will not be described here. Two different fabrics (a sand-tempered and

[1] For accounts of the excavations see: Brown, A. E., and Sheldon, H. L., 'Early Roman pottery factory in N. London', *London Archaeologist*, 1, no. 2 (1969), 38–45; 'Highgate 1969', *ibid.*, 1, no. 7 (1970), 150–154; 'Highgate Wood 1970–1971', *ibid.*, 1, no. 13 (1971), 300–304.

[2] For a description of this work see: Brown, A. E., and Sheldon, H. L., 'Post-excavation work on the pottery from Highgate', *London Archaeologist*, 1, no. 3 (1969), 60–65. The 'rim groups' of that report correspond to the rim categories listed here.

[3] This category comprises two earlier categories, A4 and A5 (in some reports it is referred to as A4/5).

a grog-tempered fabric) were produced at Highgate. This report will concentrate on the former, since the majority of the sherds examined in the early stages of processing were in this fabric.

As processing of the material continued, it became clear that the next step would be to describe the waster material in terms of vessel categories, rather than rim and base categories. The usual method, of physically reconstructing as much of the pottery as possible and classifying the reconstructed vessels, would not have been appropriate in this case, because only a small proportion of the material examined could in fact have been reconstructed. Instead, it was decided to try to reconstruct in general terms the waster output of sand-tempered vessels from the site, without actually reconstructing any individual vessel. The problem appeared to have three stages:

(i) establishing the relationships between different rim and base categories, i.e. finding out which rim and base categories belonged to the same class of vessel. Each category of vessel can then be defined in terms of a rim and a base category.

(ii) establishing the relationship between rim diameter and base diameter in each category of vessel.

(iii) estimating the height of vessels of a chosen category and rim diameter, and reconstructing their profile.

It was hoped that the waster output could then be described in terms of the hypothetical reconstructed vessels.

The project SHERD (sorting Highgate excavations' Roman debris) was undertaken with the aim of solving this three-fold problem. In this report the data available for the project are described, the theory and methods are set out, the reconstructions are presented and some comments are made on the scope and limitations of the technique. Section 2 deals with the mathematical theory, section 4 with the computer programming and analytical techniques used, and the results are in section 5. It is possible for the non-mathematical reader to skip section 2, or sections 2 and 4. A discussion of the usefulness of the techniques and the implications of the project follows in section 7.

2. *Notation, theory and models*

To solve the problem stated above it is first necessary to set up a mathematical model of the Highgate pottery as excavated. This will be a simplified representation, in mathematical terms, of a very complex real situation, namely the way in which the sherds found relate to the wasters as originally deposited.

Some algebraic notation will be needed, the rules of which are:

(a) the number x always refers to rims, and the number y to bases.

(b) lower case characters (x and y) refer to numbers of sherds found, while upper case characters (X and Y) refer to numbers of vessels represented by these sherds.

(c) subscripts are used to qualify these numbers: subscript i is used to denote the different rim categories, subscript h to denote the base categories, and subscript j to denote the different 'lots' of pottery (the material from one layer or one feature in a

trench is referred to as a lot).

(d) all numbers are given their appropriate subscripts; any characters without subscripts are matrices, i.e. they represent arrays of numbers, set out in rows and columns (see below).

This notation will see us through stage (i) of the problem; further notation will be introduced later for stages (ii) and (iii).[4]

2.1 *Relationships between the different rim and base categories*

The problem here is to find out which categories of rim and base belong together, in the sense that they come from the same category of vessel. Intuitively, we do this by counting the number of rims and bases of each category in each lot, and observing how the numbers vary from lot to lot. If a certain category of base is always common in lots where a certain category of rim is also common, and rare where that category of rim is rare, we may suppose that they belong to the same category of vessel. We need now to build up a mathematical model of this intuitive idea, in order to examine the relationships that may exist within the material.

We start by considering the numbers of vessels represented in each lot. If, in lot j, a certain proportion P_{11} of the vessels with rim of category 1 had base of category 1, we could write

$$Y_{j1} = X_{j1}P_{11}.$$

If, in addition, a proportion P_{21} of the vessels with rim of category 2 had base of category 1, we would write instead

$$Y_{j1} = X_{j1}P_{11}+X_{j2}P_{21}.$$

The proportions P_{11} etc. can range from 0 (no vessels with rim of category 1 had base of category 1) to 1 (all vessels with rim of category 1 had base of category 1). Since there are three base categories and five rim categories (the category A1 is so rare that it is best omitted), we can express all the relationships in three equations, as follows:

$$\begin{aligned}
Y_{j1} &= X_{j1}P_{11}+X_{j2}P_{21}+X_{j3}P_{31}+X_{j4}P_{41}+X_{j5}P_{51}\\
Y_{j2} &= X_{j1}P_{12}+X_{j2}P_{22}+X_{j3}P_{32}+X_{j4}P_{42}+X_{j5}P_{52}\\
Y_{j3} &= X_{j1}P_{13}+X_{j2}P_{23}+X_{j2}P_{33}+X_{j4}P_{43}+X_{j5}P_{53},
\end{aligned}$$

which we suppose to be true for all lots. Some properties of the P's should be noted as they will be needed later. The most important is that $P_{i1}+P_{i2}+P_{i3} = 1$, whether i is 1, 2, 3, 4 or 5. This expresses the obvious point that a vessel with a rim of category i must have a base of category 1, 2 or 3. It follows that if any one P in the above equations is equal to 1, then the other P's in the same column must be equal to 0, while if

[4] Some examples are given below to familiarise the reader with this notation:

symbol	meaning
x_{ji}	number of rim sherds of category i in lot j
x_{11}	number of rim sherds of category 1 in lot 1
X_{11}	number of vessels represented by these sherds
y_{jh}	number of base sherds of category h in lot j

any two P's in the same column are both equal to 0, then the third must be equal to 1. By using matrix notation we can express the above equations much more succintly as

$$Y = XP,$$

where Y is a matrix standing for Y_{j1} etc., X is a matrix standing for X_{j1} etc. and P is a matrix standing for the P's. If we knew the values of the X's and Ys we could solve this matrix equation to discover the values of the P's, and so determine the vessel categories.

In practice things are not so simple. The number of rim sherds present in a lot will vary from vessel to vessel, depending on (i) the number of sherds into which each vessel has been broken and (ii) the proportion of these sherds that remain in the lot. Some vessels will be represented by sherds in more than one lot, while parts of other vessels will be lost under baulks, etc. Although rim sherds from the same lot which obviously came from the same vessel were counted as only one rim, there is evidence that not all such 'matches' were in fact found, so that some rims would have been counted more than once. The base sherds presented a similar, but lesser, problem. We need to express these ideas in mathematical terms in order to convert the above equation, which relates to whole vessels as deposited, into a more useful equation relating to sherds as excavated. This is done by supposing that vessels with rim of category i are represented by, on average, f_i rim sherds each, but that the number of rim sherds representing any one particular vessel is a random variable with expected value equal to f_i. A further technical assumption is that these random variables have a 'Poisson distribution', so that their variance is also equal to f_i. The numbers of base sherds are also supposed to have Poisson distributions, but with expected values g_h. These assumptions will be tested in the course of the experiment. f and g can be thought of as representing the 'brokenness' of the different rim and base categories. We are now able to relate the numbers of sherds found to the numbers of vessels they represent by means of the equations

$$x_{ji} = X_{ji}f_i + d_{ji} \text{ and}$$
$$y_{jh} = Y_{jh}g_h + e_{jh},$$

in which the ds and e's represent the random part of the relationships. Assuming the variables to be uncorrelated, the variance of d_{ji} will be equal to $X_{ji}f_i$ and the variance of e_{jh} will be equal to $Y_{jh}g_h$. These equations can be written in matrix notation as

$$x = Xf + d \text{ and}$$
$$y = Yg + e.$$

By bringing in the original equation $Y = XP$, and carrying out some algebraic manipulation, we can obtain the equation

$$y = xf^{-1}Pg + \text{random terms},$$

which can be solved[5] to give an estimate of the matrix $f^{-1}Pg$. If we call this estimate a,

[5] E.g. by the method of least squares, which is described in many statistical text-books, for example: Davies, O. L. (ed.) *Statistical Methods in Research and Production* (London, 1961), p. 215.

then the matrix P is estimated by the matrix fag^{-1}, and the number P_{ih} is estimated by the number $f_i a_{ih}/g_h$ for all values of i and h.

There are in all 15 equations of the form

$$P_{ih} = f_i a_{ih}/g_h,$$

since there are 5 rim categories and 3 base categories, and therefore 15 P's. In these equations we know the values of the a's, but not the values of the P's (15 unknown numbers) or of the fs (5 unknown numbers) or of the g's (3 unknown numbers). To solve the equations fully we must find 8 more equations to bring the number of equations up to the number of unknowns. Five more can be obtained by recalling that $P_{i1}+P_{i2}+P_{i3} = 1$ for $i = 1, 2, 3, 4$ or 5, but we are still 3 short, so the equations can never be fully solved, i.e. we will not be able to estimate all the P's and all the f's and all the g's. However, the situation is not so serious as it appears. The important thing is to discover the values of i and h for which P_{ih} is positive, and for which it is zero, as this will tell us which categories of vessel actually existed. Here we observe that if a particular a_{ih} is zero then P_{ih} will be zero, and if for some h all the P_{ih} except one are zero, that P_{ih} must be equal to 1. Also, we may be able to assign values to some f_i or g_h by using archaeological knowledge, and natural constraints (e.g. that all of the f_i, g_h or P_{ih} must be zero or positive) will limit the range of possible outcomes. Some may have to be left as ratios—if all vessels with rim category i have base category h, and vice versa, we can find only the ratio f_i/g_h and never the individual values.

There is a problem that the x_i are likely to be correlated with each other from lot to lot (i.e. a lot with a large number of rims of one category usually has large numbers of rims of all categories), which may make it difficult to detect the positive a_{ih}. It may therefore be useful to work with the proportions of rims and bases of each category in each lot, instead of the actual numbers x_{ji} and y_{jh}.

To sum up, we can discover which categories of rim and base belonged to the same vessel categories by analysing the material in terms of a model which specifies how the sherds found in the excavations relate to the vessels as originally deposited.

At this point, we can define a vessel category as a rim category i associated with a base category h, and write it as A_iB_h.

2.2 *The relationship between rim diameter and base diameter in a vessel category*

If we think of all the vessels of a chosen category A_iB_h, we can see that there is likely to be some relationship between the diameters of rim and base. For example, if all the vessels were of the same shape and differed only in size, the rim diameter would be some multiple of the base diameter, whatever the size of the vessel. Such a simple relationship is perhaps unlikely, but it seems reasonable to suppose that, within a vessel category, the base diameter increases steadily as the rim diameter increases. In mathematical terms, we could say that the base diameter r and the rim diameter q are related by the equation

$$r = h(q),$$

where h is a monotone increasing function.

Given the complete vessels, it would be a simple matter to plot r against q graphically and to examine the function h. However, we have only the measured diameters of individual rims and bases, from which we can construct cumulative density functions $F_j(q)$ and $G_j(r)$,[6] so that $F_j(q)$ is the proportion of rims (of the category we are considering) which have a diameter less than or equal to q, and $G_j(r)$ is the proportion of bases which have a diameter less than or equal to r. The situation becomes more complicated if one base category is associated with (for example) two rim categories, giving rise to two vessel categories. There is no way of telling, a priori, which size of base belongs to which vessel categories, and part of the task must be to examine this point. To investigate the problem in more detail, we will take first the simple case where both rim and base category relate to only one vessel category. In this case we can transform the equation

$$r = h(q),$$

which relates to one complete vessel, to the new equation

$$G_j(r) = F_j(h(q)),$$

which refers to all the relevant rims and bases in each lot. This equation is saying, for example, that if 2″ bases are associated with 6″ rims, and 50% of rims have a diameter of less than 6″, then 50% of bases will have a diameter of less than 2″. Implicit in this equation is an assumption about the nature of the brokenness terms f_i and g_h of section 2.1. We do not need to assume that either f_i or g_h is independent of diameter, but we do need to assume that the ratio f_i/g_h is independent of vessel size, in other words that the average of the ratio of number of rim sherds to number of base sherds does not vary with vessel size. If this were not so the function h could be distorted by (for example) a preponderance of sherds from large rims.

We can now take the above equation and try to solve the problem by estimating the form of the function h, remembering that we have only estimates of the cumulative density functions F and G. To simplify, it is assumed that h is linear, i.e. that the relationship between q and r can be described by means of a straight-line graph. Bearing in mind the relatively small amount of data available it is unlikely that any more complicated function would be necessary.

In the time available it was not possible to solve the problem algebraically, even for the simple case described above. A graphical method was devised in order to arrive at a practical solution. As it is of an 'ad hoc' nature, it will be described in the section on operations, and not under theory.

[6] The use and interpretation of these functions have been discussed in an earlier report: Orton, C. R., 'The production of pottery from a Romano-British kiln site: a statistical investigation', *World Archaeology*, 1 (1970), 343–358.

2.3 *Heights of vessels and reconstruction of profiles*

By this stage we have established the existence of a number of vessel categories, and in each category we know the relationship between rim and base diameter. We can choose drawings of sherds in the appropriate categories and attempt to reconstruct the profile between them. This will be done by fitting an equation to the shape of each sherd (omitting the details of rim and foot), extending the curves of the sherds to form parts of profiles, and adjusting the distance between rim and base (i.e. the height) until a smooth profile is achieved, consisting of the whole base sherd, part of its extension merging smoothly into the downward extension of the rim, and finally the whole rim sherd. The problem can be stated more readily in terms of co-ordinate geometry.

Taking as axes the vertical axis of the pot (x-axis) and a horizontal axis in its base (which is assumed to be flat)—the y-axis—we fit curves to the shapes of the sherds, of the form

$$y_1 = d_1(x) \qquad \text{(base)}$$

and

$$y_2 = d_2(x-h) \qquad \text{(rim)},$$

where h is the unknown height of the vessel, x represents distance measured vertically upwards from the base, y represents horizontal distance from the vertical axis, and d_1 and d_2 express the shape of the base and rim curves. This system of notation is not related to that used in section 2.1. The two curves will meet when

$$d_1(x) = d_2(x-h),$$

bearing in mind that we are interested only in roots (solutions) greater than 0 but less than h. For the join between the two curves to be smooth (no carinations have been observed on the normal Highgate pottery) they must have the same gradient (slope) at the point where they meet, i.e. this point must represent two equal roots of the equation given above.

In practice it was decided to adopt quadratic equations to represent the shapes of the sherds. They have the advantage of being easy to use, and fit the shapes of the pottery reasonably well (see section 4). However, other sorts of curves might be needed for other pottery. The equation for the base is written

$$y = a_1x^2+b_1x+c_1,$$

and that for the rim is written

$$y = a_2(x-h)^2+b_2(x-h)+c_2.$$

The a's, b's and c's are now straightforward numbers: the subscript 1 will always refer to bases and the subscript 2 to rims. The two points where the rim and base curves meet are given by the roots of the equation

$$a_1x^2+b_1x+c_1 = a_2(x-h)^2+b_2(x-h)+c_2$$

i.e.

$$(a_1-a_2)x^2+(b_1-b_2+2a_2h)x+c_1-c_2+b_2h-a_2h^2 = 0. \qquad \text{(A)}$$

The curves will meet smoothly if equation (A) has equal roots, i.e. if

$$(b_1-b_2+2a_2h)^2 = 4(a_1-a_2)(c_1-c_2+b_2h-a_2h^2)$$

which becomes

$$a_1a_2h^2-(a_1b_2-a_2b_1)h+\tfrac{1}{4}(b_1-b_2)^2-(a_1-a_2)(c_1-c_2) = 0 \qquad \text{(B)}$$

on rearranging the terms to form a quadratic equation in h. We would like to be able to solve this equation for its roots h_1 and h_2, determine whether they are feasible (a feasible height must be positive, and when substituted in (A) must give a root between 0 and h, because the two curves must meet between the rim and base), and if they are, put them forward as possible vessel heights. Usually only one root will be feasible, but the possibility of two feasible roots cannot be ignored.

The snag is that (B) may not always have a positive root. We must therefore examine (B) closely to find out when there will be a positive root, and when not. A study of the drawings showed that

$$\left.\begin{array}{rl} \text{(i)} & c_2 > c_1 > 0 \\ \text{and (ii)} & b_1 > 0, \quad b_2 < 0 \\ \text{and (iii)} & a_2 < 0 \end{array}\right\} \text{ in all cases,}$$

but that there were two types of base curve; convex curves with $a_1 < 0$ and concave curves with $a_1 > 0$. It can be shown that concave bases will always give a positive root, but that convex bases will only give a positive root under the condition that

$$(a_1 - a_2)(4a_1a_2(c_1 - c_2)+a_1b_2^2 - a_2b_1^2) > 0.$$

The problem of forcing a solution when $a_2 < a_1 < 0$ was considered. In this case the base curve must touch the rim curve externally for a solution to exist. For this to happen, the maximum value of y on the base curve must be greater than or equal to the maximum value of y on the rim curve, i.e.

$$c_1 - \tfrac{1}{4}b_1^2/a_1 \geqslant c_2 - \tfrac{1}{4}b_2^2/a_2$$

or, since a_1 and a_2 are both negative,

$$b_1^2/|a_1| - b_2^2/|a_2| \geqslant 4(c_2 - c_1),$$

where the modulus sign (| |) denotes the absolute value of a_1 or a_2. This can best be achieved by decreasing $|a_1|$ until equality is reached. The value of a_1 so obtained represents the smallest change from the original value which will give a solution. Details and examples are given in the following sections. Other distortions of the original shape are of course possible, but it will be shown that a_1 is the coefficient most 'at risk' when drawings of sherds are made.

3. *The data*

Details of twelve lots of pottery were used in the project. Six of these lots came from a large dump of waster material and baked clay, two came from pits, thought to have been dug to provide clay and later filled with rubbish, two came from a ditch and two from the flue and chamber of one of the kilns.[7] There were in all 4650 rims and 1700 bases, of which just over half (from nine lots) were ready in time to be used in stage (i). The exclusion of sherds which could not be measured, and of those from two small lots, reduced the numbers available for stage (ii) to 3650 rims and 1500 bases. The information was stored on index cards—one for the rims and one for the bases from each lot. Examples are shown in Table 1.

TABLE 1: Examples of index cards

(a) rims:

	<2″	<3″	<4″	<5″	<6″	<7″	<8″	<9″	<10″	<11″	<12″	⩾12″	all	n.m.*
A2							2	3	2	3	1		11	
A3								1			2		3	
A4			1	4	18	10	6	3		1			43	7
A6				2	1		1	2		1			7	1
A7				1									1	1
total													65	9

(b) bases:

	<1″	<2″	<3″	<4″	<5″	<6″	<7″	<8″	<9″	⩾9″	all	n.m.*
B1			2	3	2						7	1
B2		2	2	3	1						8	1
B3		3	11	1							15	2
total											30	4

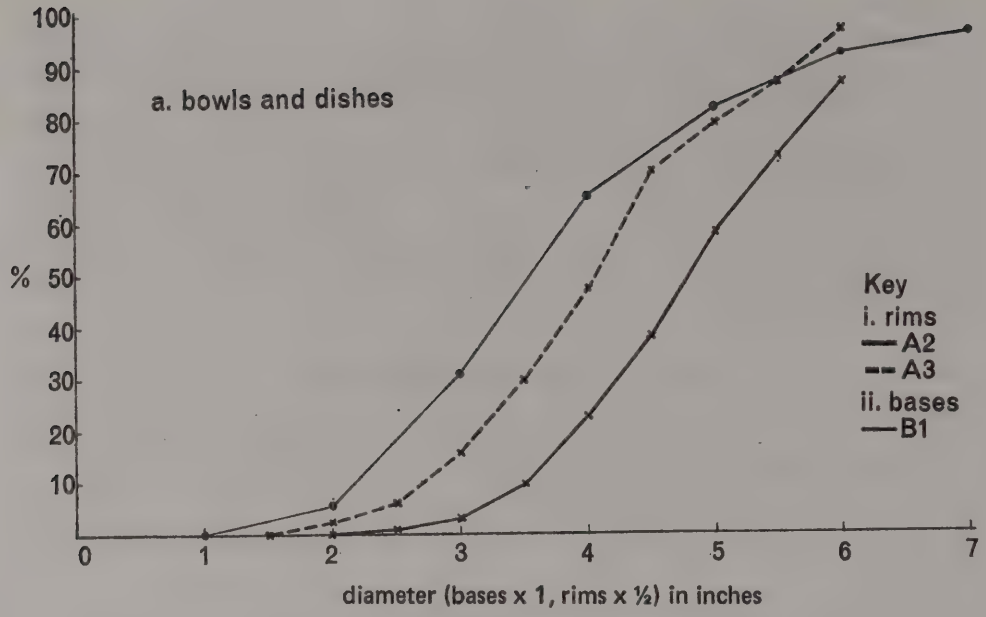
* n.m. = not measured

For stage (ii) the information was used in the form of cumulative frequency curves, sets of curves being drawn for each lot and for 'all lots'. The latter are shown in Figure 1.

For stage (iii) drawings of individual rims and bases were used. As they showed variation within each category, the following sub-categories were set up:

RIMS—A2: (a) shallow—the sherd slopes inwards below the rim.
(b) straight—the sherd drops vertically from the rim.
(c) bulbous—the sherd slopes outwards below the rim.

[7] A series of mimeographed reports on this pottery is being prepared by students at the City Literary Institute. To date two—'Pottery associated with pit 3 and kiln 3 in Highgate Wood' (1969) and 'Some pottery from ditch 1 in Highgate Wood' (1971)—have been lodged in the library of the Institute of Archaeology, London.



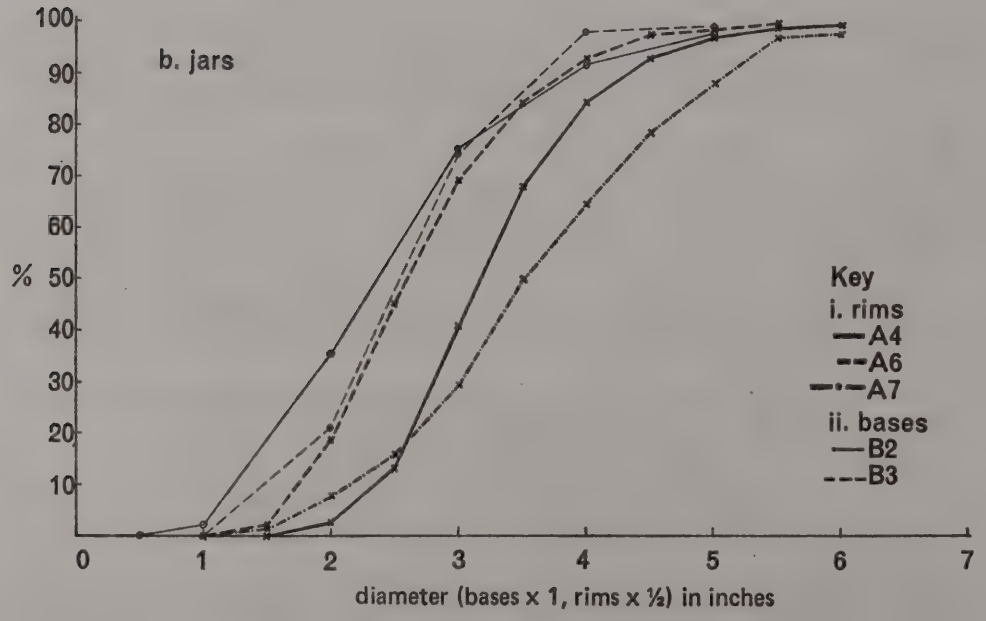


Fig. 1 Cumulative frequency curves for 'all lots'.

A3: (a) shallow
(b) straight } as for A2.

A4: (a) strongly shouldered.
(b) more 'streamlined'.

A6: (a) with pronounced shoulder.
(b) with less pronounced shoulder.

A7: (a)
(b) } as for A6.

BASES—B1: (a) shallow—the sherd rises slowly from the base and is gently curved.
(b) curved—the sherd is more strongly curved.
(c) steep—the sherd rises steeply from the base, and tends to B2 in form.

B2: (a) with convex profile above initial concavity.
(b) with concave profile.

B3: (a)
(b) } as for B2.

Drawings of the base and rim sherds used are given as Figures 2 and 3.

4. *Programs and operations*

The information from the index cards was stored on magnetic disc in Honeywell Information Systems' computer time-sharing service, and all programs were written in the time-sharing language BASIC. Two files, RIMS and BASES, were created, with RIMS to contain all the information of the rim index cards for the twelve lots and BASES to contain the corresponding information from the base index cards. The opening lines of RIMS are shown as Table 2 to illustrate the format. The three numbers in line 100 are the number of categories, the number of lots and the number of size-groups; line 110 gives the lower bound of each size-group (as diameter in inches), and line 120 the names of the categories. From line 130 the information is stored systematically by category within lot, the string of numbers in each line being the numbers of rims in each size-group, as defined in line 110, the last figure being the number of non-measurable sherds. It was intended that these files would be used for the first two stages of the project. Some lots were written up in RIMS although the base data was not available at the time, in the hope that they would become available before the end of the project.

The first program of the project was SHERD1, which reduced the data of RIMS and BASES to a form suitable for use in stage (i), and stored them in two new files, RIMMAT and BASMAT. The format of RIMMAT is shown in Table 3; line 1000 gives the number of categories and the number of lots, line 1010 the names of the lots, line 1020 the numbers of A2 rims in each lot, and so on.

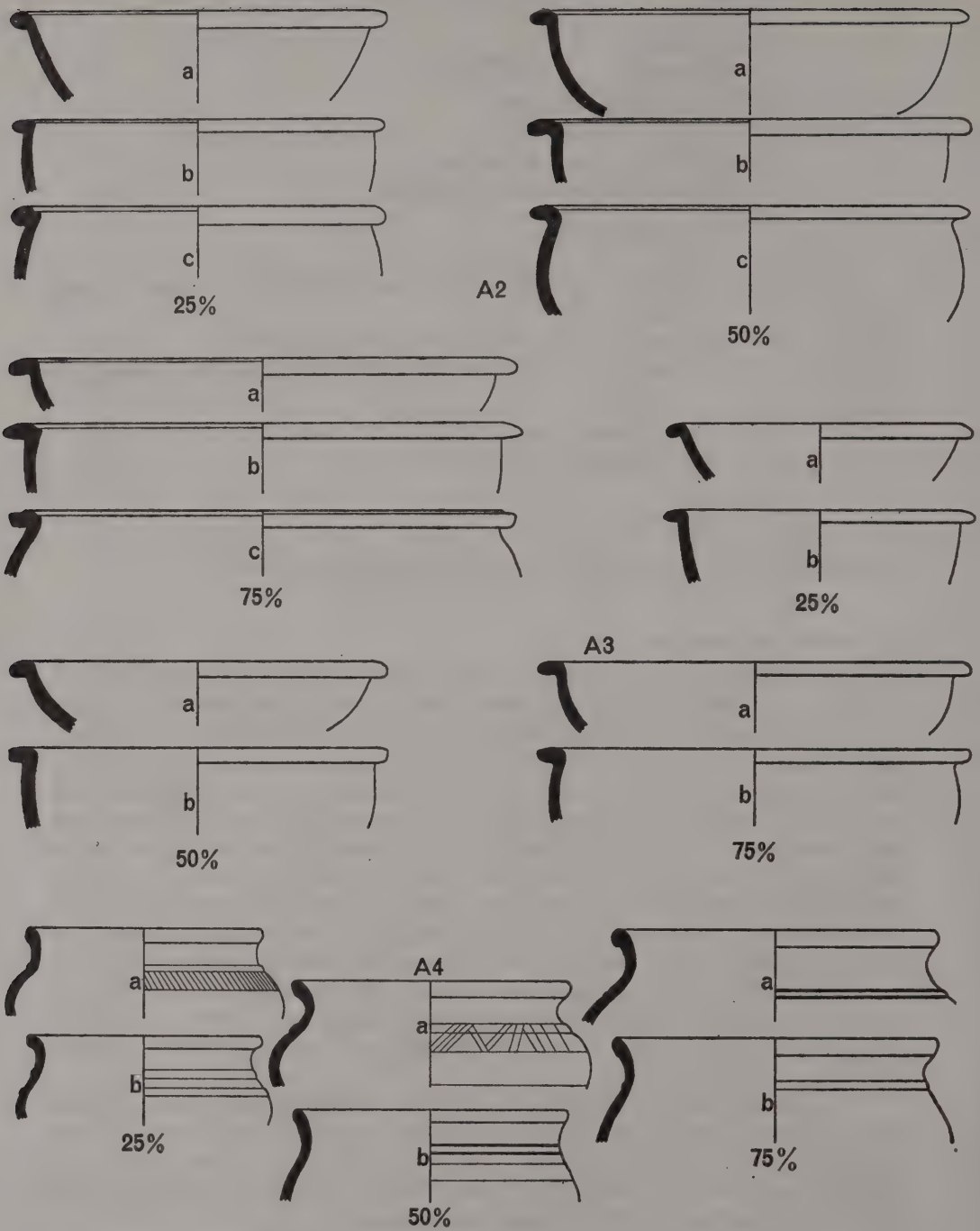


Fig. 2 Rim sherds used in the reconstructions (¼ scale).

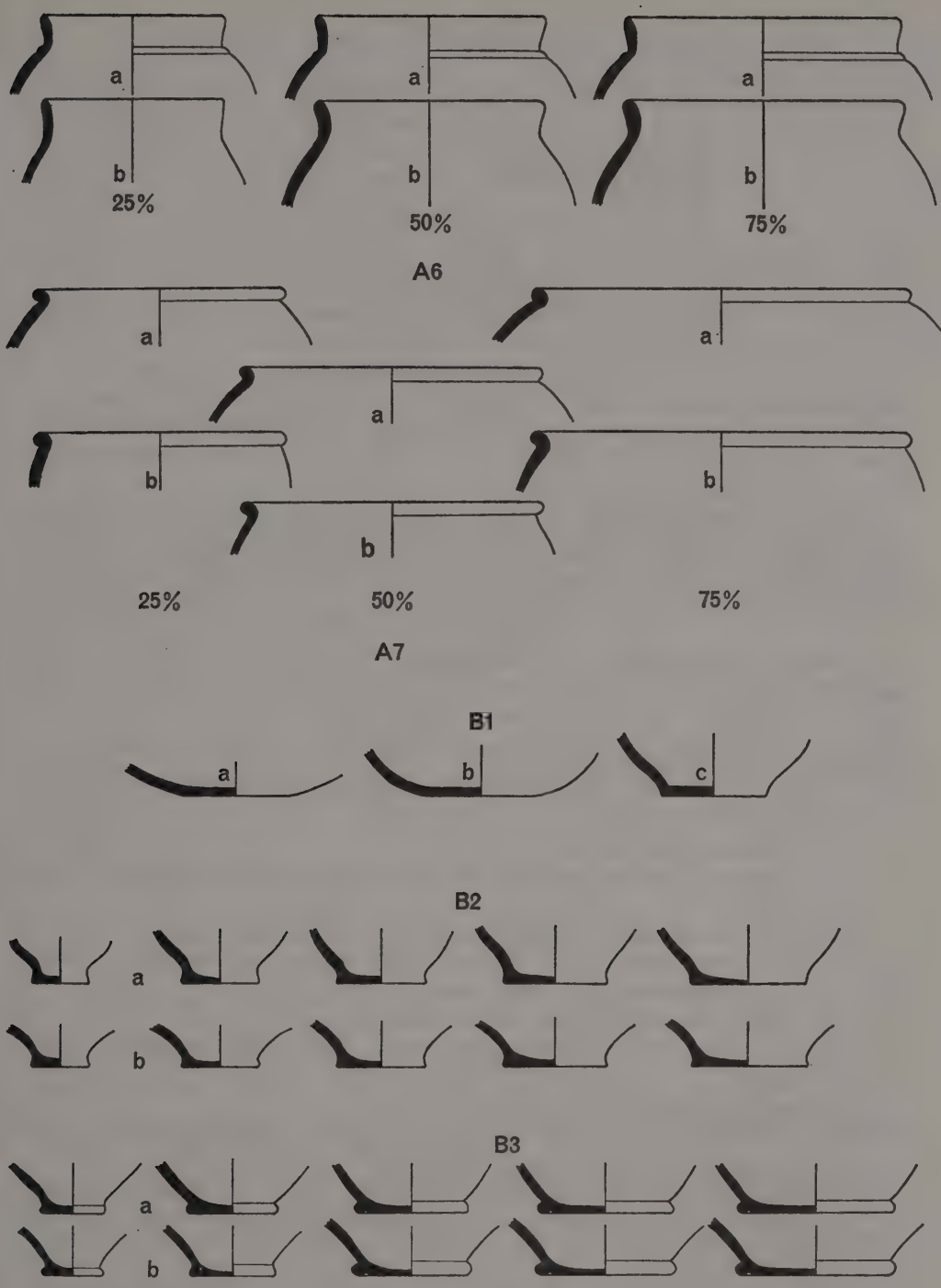


Fig. 3 Rim and base sherds used in the reconstructions (¼ scale). (only one base of each sub-category of B1 is shown).

TABLE 2: Part of the file RIMS

```
100  5, 18, 12
110  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11, 12
120  A2, A3, A4, A6, A7
130  T2L2
131  0,  0,  0,  0,  0,  0,  2,  3,  2,  3,  1,  0,  0
132  0,  0,  0,  0,  0,  0,  0,  1,  0,  0,  2,  0,  0
133  0,  0,  1,  4, 18, 10,  6,  3,  0,  1,  0,  0,  7
134  0,  0,  0,  2,  1,  0,  1,  2,  0,  1,  0,  0,  1
135  0,  0,  0,  1,  0,  0,  0,  0,  0,  0,  0,  0,  1
```

TABLE 3: Part of the file RIMMAT

```
1000      5       9
1010    T2L3    T6L3    T8F3   T24L3   T24F5   T24IK T33F1L1 T42F1 T42SEF1
1020      59      47      13      69      30      33      85     48      39      A2
```

Stage (i) was attempted in two ways, which will be referred to as the 'unweighted' and 'weighted' methods. Program SHERD2 was written for the former. It was noted in section 2 that stage (i) was essentially the problem of solving the matrix equation

$$y = xf^{-1}Pg + \text{random terms.}$$

SHERD2 uses the method of least squares to estimate $f^{-1}Pg$ by the matrix a, given by

$$a = (x'x)^{-1}x'y.$$

The operation of SHERD2 is as follows:

1. calculate a and print it as a matrix with columns corresponding to base categories.
2. print the inverse matrix $(x'x)^{-1}$.
3. calculate the residual sum of squares for each base category in turn, and print them.
4. calculate and print the t-statistic[8] of each coefficient a_{ih}.
5. ask the user if he wants to repeat 1–4 using percentages in each lot, instead of actual numbers. If he does, repeat 1–4.
6. restrict calculations to the first base category.
7. ask the user to choose the coefficients a_{i1} which he thinks are likely to be positive.
8. repeat 1–4 on the chosen set of coefficients.
9. calculate the test statistic u giving the increase in residual error due to the elimination of the chosen rim categories.

(The user must now test u by an F-test[9] and decide whether the chosen coefficients are adequate. If they are not, he can go back to 7 and choose a new set. If they

[8] *op. cit.* fn. 5, p. 223.
[9] *ibid.* p. 230.

are adequate, but percentages are being used, he can choose to use actual numbers for a final run with chosen coefficients.)

10. if requested, carry out this final run of steps 1–3.
11. calculate and print the standard deviations of the coefficients.
12. move to the next base category and go back to step 7.

It should be noted that after step 7, coefficients can only be brought back in, and no more can be eliminated. A separate run of the program is needed if it is required to eliminate more variables at any stage. There are a number of constraints which are best applied by the user, e.g. no column of the matrix a can consist entirely of zeros.

An objection to using an unweighted least-squares method in this case is that it assumes that the error variances of the y_{jh} are constant from lot to lot, while our model postulates that the error variance increases as y_{jh} increases, and is approximately proportional to it. This suggests that instead of minimizing the overal residual sum of squares we should work on each base category separately, minimizing the weighted sum of squares, with weights equal to $1/y_{jh}$ for each lot. The program SHERD3 does just this. It operates in the same way as SHERD2, except that steps 1–4 are carried out for each base category in turn, instead of all at once, and the option of converting the data to percentages is not available. Part of the aim of the project was to assess the relative usefulness of these two approaches.

When we have provisionally decided on the best set of coefficients a_{ih} we would like to test them in some way. Using them and the matrix x we can predict the numbers of bases of each category in each lot, and compare our predictions with actual numbers y_{jh}. We can also estimate the error variance of each number y_{jh}, and so carry out a chi-squared test[10] on the residuals (i.e. the differences between the predicted and actual numbers). All this is done in the ancillary program RESIDU, whose operation is as follows:

First the user must give his chosen coefficients a_{ih}

1. calculate, for each base category in turn,
   (i) the predicted value of y_{jh} for all lots j,
   (ii) the residuals and their squares,
   (iii) their contribution to the chi-squared statistic, allowing for errors in the x's as well as in the y's.
2. print the results of 1 in tabular form, with one row for each lot.
3. calculate and print the total value of chi-squared.

This completes the programs written for stage (i). RESIDU was used to examine the outcome of both SHERD2 and SHERD3.

It was originally intended to start stage (ii) by considering just the median diameter of each category in each lot and ignoring the rest of the distributions. To this end the program SHERD4 was planned. It soon became clear that, even with this

[10] *ibid.* p. 285.

limited objective, SHERD4 could probably not have been accommodated in the disc space permitted in the BASIC system, and it was therefore abandoned.

The problem of establishing relationships between base and rim diameter became (under the assumptions given in section 2) the problem of finding 'transformations' which could be applied to the cumulative frequency curves of the base categories to make them correspond as closely as possible to the cumulative frequency curves of the rim categories. As the exercise was restricted to linear relationships, only linear transformations were allowed, i.e. only the movement of points on the curve by (a) multiplication by a constant or (b) addition of a constant. Movements of type (a) are needed to make the slopes of the two curves the same in their central parts, while movements of type (b) can then be used to make the curves coincide as much as possible. In practice the solution was not so simple, because each base category was related to more than one rim category. Examination of the 'all lots' cumulative frequency curves suggested possible linear transformations, which were then tested on the curves for the individual lots. Some divergence between the transformed base curves and the rim curves can be expected, especially in lots with appreciable numbers of 'non-measurable' sherds. The results were expressed as a range of possible transformations that would satisfy all the data simultaneously. The method did not therefore give a precise answer, but rather a choice of answers that had to be carried forward and tested in the final stage.

Some experiments on vessels, whose complete profiles were known, were needed before stage (iii) could be tackled. Two were chosen: a 'poppy beaker' of category A6B3 and a bowl of category A2B1.

(a) *the beaker.* The relevant part of the profile (excluding rim and base detail) had a height of 22 units (1 unit = 0.2 in.= 5 mm.). This was divided into three parts: the 'base', the 'rim' (with heights of 7 and 8 units respectively) and a supposedly unknown 'middle'. The standard program MULFTS was used to fit quadratic and cubic curves to both rim and base. Both gave excellent fits to the curves, but the cubic curve diverged rapidly from the profile when projected beyond the base or rim (see Fig. 4(b)) while the quadratic curve diverged less strongly (Fig. 4(a)), confirming the decision to use quadratic curves to represent the shapes of the sherds. A suggestion that gamma functions might provide a suitable family of curves was not followed up. The equation for h had two possible roots, $h = 18.5$ and $h = 25.7$. The profiles that these would give are shown as Figs. 4(c) and (d). In practice the latter would be rejected because it causes unnecessary distortion to the shape of the rim sherd. The surviving value of h (18.5) represents a decrease of 3.5 units (16%) on the known original height.

(b) *the bowl.* This vessel had a height (excluding rim detail) of 18 units, which was divided into a 'base', a 'rim' (each 6 units high) and an unknown 'middle'. Again, it was found that quadratic curves fitted the rim and base very well (Fig. 5(a)). The equation for h had roots $h = 12.7$ and 16.7, but the former is a spurious solution as it implies that base and rim curves meet above the rim. The accepted solution, 16.7, represents a decrease of 1.3 units (7%) on the original height (see Fig. 5(b)). It was

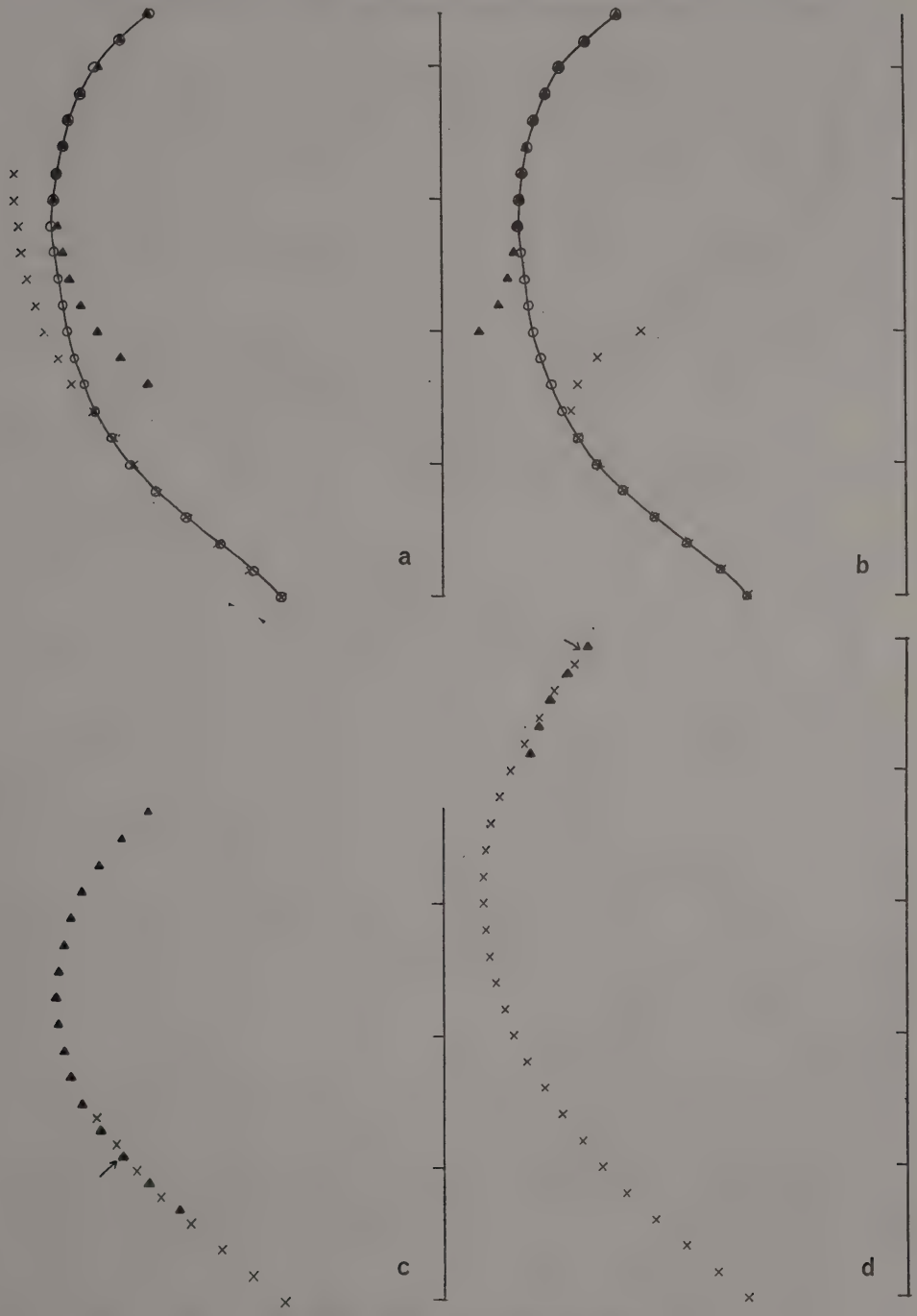


Fig. 4 Experimental reconstructions of the A6B3 vessel ($\frac{3}{16}$ scale). (see figure 5 for key).

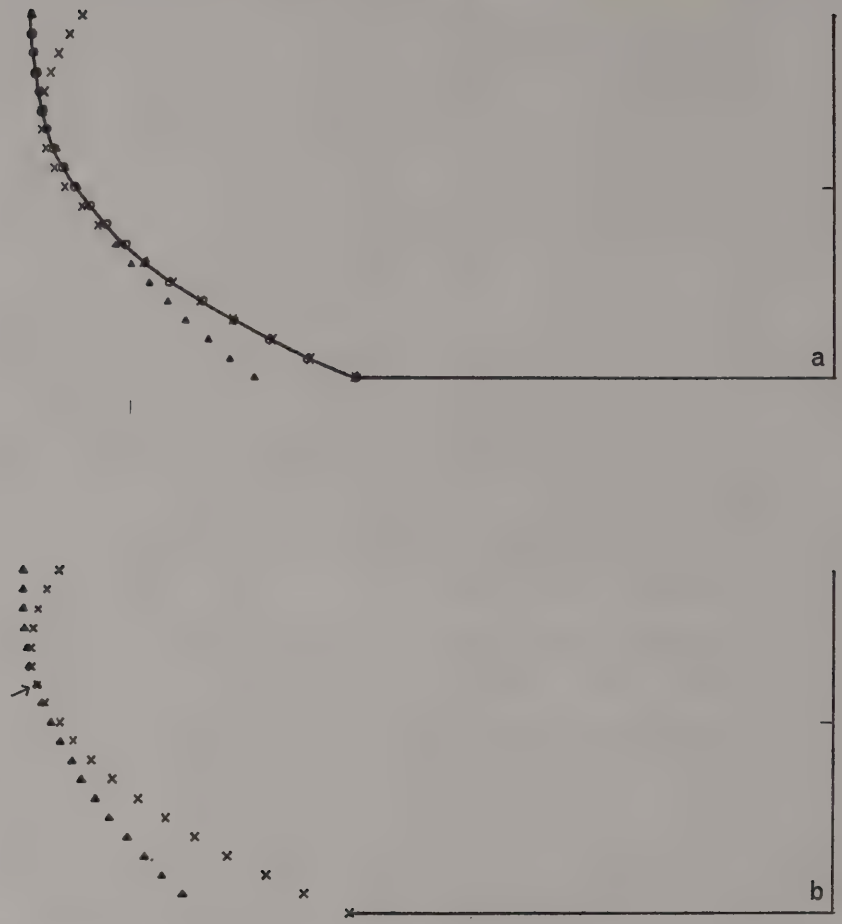


Fig. 5 Experimental reconstructions of the A2B1 vessel (¼ scale).

Key

⊙ = points of original profile
× = points of projected base profile.
▲ = points of projected rim profile.
↗ = point where the base and rim curves meet.

concluded that, although the method appeared to work reasonably well, some shortening of vessels could be expected.

To give examples over the range of vessels produced, it was decided to reconstruct three sizes of vessel in each established category. The sizes chosen were (i) at the first quartile of the distribution of sizes (ii) at the median and (iii) at the third quartile. As 25% of vessels in the distribution would be smaller than (i), it was called the '25% vessel' (e.g. A2B1, 25%) and similarly (ii) and (iii) were called the 50% and 75% vessels. If, as seems likely, 'brokenness' increases with size, rather more actual vessels

than these percentages indicate will be smaller than the stated sizes.

Each combination of rim and base sub-category was to be reconstructed in the hope that some combinations could be eliminated. The problem of choosing the best relationship from amongst those produced by stage (ii) had also to be considered.

Two programs were written for stage (iii). The first, SHERD5, fitted a quadratic equation to a given curve (using orthogonal polynomials[11] and the method of least squares). This equation was then used to project the curve for a specified height either upwards (for bases) or downwards (for rims). Statistical 'confidence intervals' about each projected point were also calculated, as it was anticipated that such intervals would be useful in cases where it was necessary to adjust the projection from either rim or base to effect a reconstruction.

A second program, SHERD6, was written to carry out the operations described in section 2.3. The steps in its operation were:

(i) fit quadratic curves to the chosen rim and the chosen base.
(ii) form the quadratic equation for the height h, and test to find out if it has a positive root.
(iii) calculate and print any roots.
(iv) calculate the heights at which the two curves meet, and print them if they are positive but less than the corresponding root.
(v) ask the user to choose the more suitable root.
(vi) using the chosen value of h, reconstruct the entire profile and print the co-ordinates of the points of this profile.

A third program would have been written to carry out the forcing operation described at the end of section 2.3, if time had permitted. As the need for the program was not fully appreciated until after the end of the computer part of the project, all such forcing operations had to be carried out manually.

SHERD6 was used to attempt reconstructions of all 'possible' vessels, i.e. of all vessel categories, of all sizes within those categories and of all combinations of rim and base variations within the sizes. As expected, the B1 bases and the concave B2 and B3 bases gave no trouble, but the convex B2 and B3 bases either failed to produce roots for h or made the base and rim curves meet above the rim in almost every case. At first the trouble seemed to be that the curve projected downward from the rim met the curve of the base at too great an angle to the vertical, and that the solution lay in forcing the projected rim curve outwards to decrease this angle. When SHERD5 was used to do this, the resulting curves gave taller and taller vessels, but no appreciable decrease in the angle at which the curve met the base (see Fig. 6 for a typical example). A further examination showed that the real cause of the difficulty lay in the shape of the base. In the experiments with the known vessel of category A6B3 it had been found that the equation of the base curve was

$$y = 5.90 + 1.33x - 0.044x^2,$$

[11] *ibid.* p. 242.

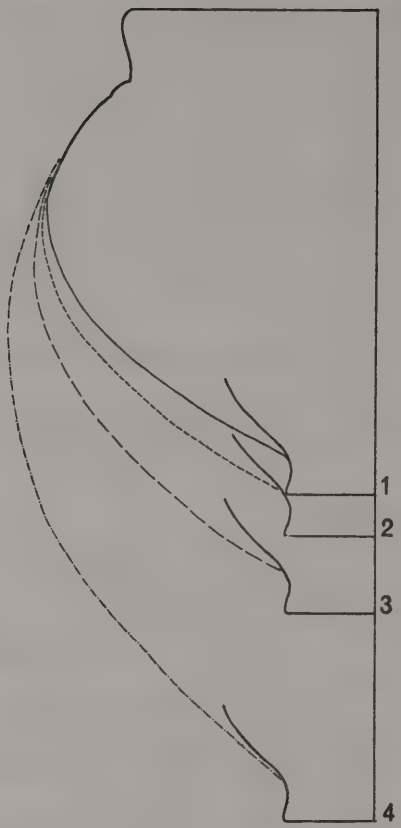


Fig. 6 1 = projected rim profile, meeting base at wide angle.
2 = rim profile slightly adjusted, still meets base at wide angle.
3 = rim profile further adjusted, still meets base at wide angle.
4 = rim profile greatly adjusted, still no satisfactory join with base.

while for the B2 and B3 base sherds the coefficients of x (i.e. b_1) were generally smaller (in the range 0.95 to 1.10) and the coefficients of x^2 (i.e. a_1) were also generally smaller (-0.050 to -0.075), though they were greater for some B2s (-0.032), which had however unusually low values of b_1 (0.93). The combined effect of these two discrepancies is to produce altogether narrower vessels when the base curves are projected—so narrow in fact that no reconstruction with the rim curve was possible. Of the two coefficients, b_1 determines the initial angle that the base curve makes with the vertical axis, while a_1 determines the 'curvature' of the profile. Coefficient a_1 is more sensitive to small drawing errors than b_1, and it was argued that in the bulk of the base drawings the implied value of a_1 was too low, i.e. the sherd had been drawn slightly too curved. The forcing procedure of section 2.3 was therefore used to 'straighten out' the curve

of the convex bases so that complete profiles could be made (see section 5, stage (iii) for details). It could however also be argued that in fact the angles (given by b_1), not the curvatures (implied by a_1), were wrong. This is less likely as it implies a considerably lower degree of competence on the part of the draughtsman, but it cannot be completely dismissed. If the forcing were done by adjusting b_1 instead of a_1 the outcome would be much shorter, squatter vessels, with much broader base angles. The possibility of simultaneous changes in a_1 and b_1 should probably be considered, although it would create large numbers of possible profiles.

5. *Results*

We now revert to the notation of sections 2.1 and 2.2 to present the results of the first stage of the experiment. The meanings of the symbols used have been given in those sections, the subscripts used to denote the various rim and base categories are given below:

rim categories

subscript	1	refers	to	category	A2
,,	2	,,	,,	,,	A3
,,	3	,,	,,	,,	A4
,,	4	,,	,,	,,	A6
,,	5	,,	,,	,,	A7

base categories

subscript	1	refers	to	category	B1
,,	2	,,	,,	,,	B2
,,	3	,,	,,	,,	B3

When actual numbers of sherds in each lot were used, the program SHERD2 gave the following equations as its estimate of how the data fitted the model:

$$y_1 = 0.18x_1 + 0.12x_2 + 0.23x_3 - 0.11x_4 - 0.17x_5,$$
$$y_2 = 0.13x_1 + 0.04x_2 - 0.13x_3 + \underline{0.34}x_4 + \underline{0.35}x_5,$$
$$y_3 = 0.11x_1 - 0.15x_2 + 0.26x_3 + \underline{\underline{0.55}}x_4 - \underline{0.17}x_5.$$

When percentages were used instead of numbers of sherds, the corresponding equations were:

$$y_1 = \underline{0.80}x_1 + 0.98x_2 - 0.09x_3 + 0.03x_4 + 1.19x_5,$$
$$y_2 = \underline{0.03}x_1 + 0.30x_2 - 0.06x_3 + \underline{0.40}x_4 + \underline{0.96}x_5,$$
$$y_3 = 0.17x_1 - 0.28x_2 + \underline{1.15}x_3 + \underline{0.59}x_4 - \underline{1.15}x_5.$$

The convention is adopted that coefficients which are statistically significant[12] are underlined. Formally, the first equation says that the best estimate of the number of B1 bases in a lot is 0.18 times the number of A2 rims plus 0.12 times the number of A3 rims plus 0.23 times the number of A4 rims minus 0.11 times the number of A6 rims minus 0.17 times the number of A7 rims, and the other equations can be read similarly. As they stand, these equations do not answer our question 'which bases relate to which rims?' or in more mathematical terms 'which coefficients are really

[12] *Ibid.* p. 223. The 95% confidence level was used. The outcome of this test should not in this case be taken as more than a useful indication.

positive, and which are merely products of the randomness of the situation?' We must try to interpret the equations, using all the information at our disposal. It should first be noted that at least one coefficient in each row and one in each column must be positive (because each base category must be related to at least one rim category, and vice versa) and that no coefficient can really be negative. Using the criterion of statistical significance, the 'percentage' equations indicate that category B1 is related to A2, B2 to A6 and A7, and B3 to A4. To examine the relationships in more detail, each base category was then considered separately, and the effects of choosing different coefficients as being probably positive were calculated.

For B1, choosing the rim categories with the largest and most significant coefficients (not always the same thing) gave:

$$y_1 = \underline{1.25}x_1,$$
$$y_1 = \underline{0.89}x_1 + \underline{0.97}x_2,$$
$$y_1 = \underline{0.85}x_1 + \underline{0.80}x_2 + 0.91x_5.$$

B1 thus seemed to be related to A2 and A3, and possibly also to A7. The two possible choices were converted back into numbers, and the equations became:

$$y_1 = 0.39x_1 + 0.37x_2 \qquad \text{—(1)}$$

and

$$y_1 = 0.31x_1 + 0.36x_2 + 0.26x_5 \qquad \text{—(1a)}$$

For B2 bases, taking the significant coefficients led to

$$y_2 = 0.44x_4 + 1.09x_5,$$

with no other x having an appreciable effect on y_2. So it seemed that B2 was related to A6 and A7, and in terms of numbers of sherds the equation

$$y_2 = 0.24x_4 + 0.21x_5 \qquad \text{—(2)}$$

was obtained.

The equation for B3 had two large coefficients, and using them alone gave

$$y_3 = \underline{0.95}x_3 + 0.68x_4,$$

confirming that B3 was related to A4 and A6. The equation in terms of numbers of sherds was

$$y_3 = 0.26x_3 + 0.52x_4 \qquad \text{—(3)}$$

The equations (1), or (1a), (2) and (3) can be taken to represent the relationships between the rim and base categories, but it must be appreciated that, although we can be reasonably sure of which coefficients are positive and which are zero, the actual values of the positive coefficients are subject to errors.

The weighted method SHERD3 was next used, and gave the following equations, which correspond to (1), (1a), (2) and (3) above:

$$y_1 = 0.37x_1 + 0.29x_2 \qquad \text{—(4)}$$

$$y_1 = 0.29x_1 + 0.28x_2 + 0.30x_5, \qquad \text{—(4a)}$$

$$y_2 = 0.21x_4 + 0.25x_5, \qquad \text{—(5)}$$

$$y_3 = 0.22x_3 + 0.54x_4. \qquad \text{—(6)}$$

The results of SHERD2 are thus broadly confirmed.

The program RESIDU then compared the actual numbers of bases in each lot with the numbers predicted by the equations (1) to (6), using a chi-squared goodness of fit test. The results were:

unweighted method		*weighted method*	
B1 bases: equation (1):	$\chi^2_7 = 14.8$	equation (4):	$\chi^2_7 = 19.2$
B1 bases: equation (1a):	$\chi^2_6 = 13.5$	equation (4a):	$\chi^2_6 = 16.6$
B2 bases: equation (2):	$\chi^2_7 = 10.9$	equation (5):	$\chi^2_7 = 12.6$
B3 bases: equation (3):	$\chi^2_7 = 5.2$	equation (6):	$\chi^2_7 = 6.5$

Throughout, the best fit was given by the unweighted method, which was therefore preferred to the weighted. The reason for this apparent anomaly seems to be that the weights depend on the coefficients, which are initially unknown. The weights used were therefore only approximate, and were not close enough to the best weights to bring any improvement. An iterative method, using the results of one run to provide the weights for the next, might have been the answer to this problem. Overall, the data fit the model adequately, but not particularly well. A large part of the chi-squared statistic came from one of the lots from a ditch, which had 'too many' B1 bases and 'not enough' B2 bases. On examination, this lot was found to include a small number of B1 bases and A7 rims in the grog-tempered fabric, which seemed to explain the excess of B1 bases. Had time permitted, the analysis should have been repeated excluding all grog-tempered sherds, but as they were few it was decided to accept equation (1) in preference to (1a) and to ascribe the difficult category A7B1 to the minority fabric. There may however be some vessels of this category in the sandy fabric.

It now remains to estimate the matrix P and the 'brokenness' terms f_i and g_h from the coefficients of equations (1) to (3). Writing them as

$$\begin{aligned} y_1 &= 0.39x_1 + 0.37x_2 \\ y_2 &= \qquad\qquad 0.24x_4 + 0.21x_5 \\ y_3 &= \qquad 0.26x_3 + 0.52x_4 \end{aligned}$$

we can see that P_{11}, P_{21}, P_{33}, and P_{52} are all equal to 1, i.e. that all vessels with A2 or A3 rims have B1 bases, all vessels with A4 rims have B3 bases and all vessels with A7 rims have B2 bases. So we can write the equations relating to vessels as

$$
\begin{aligned}
Y_1 &= X_1 + X_2 \\
Y_2 &= P_{42}X_4 + X_5 \\
Y_3 &= X_3 + P_{52}X_4,
\end{aligned}
$$

with only P_{42} and P_{52} (which equals $1-P_{42}$) still unknown. The ratios of the f's and g's are:

$$
\begin{aligned}
g_1/f_1 &= 0.39 \\
g_1/f_2 &= 0.37 \\
g_2/f_3 &= 0.26 \\
g_2/f_5 &= 0.21.
\end{aligned}
$$

It is unlikely that the g's are greater than 1, as two sherds of the same base in the same lot would not often go unrecognized, but they might perhaps be slightly less than 1. Putting them equal to 1, we find that $f_1 = 2.6$, $f_2 = 2.7$, $f_3 = 3.8$ and $f_5 = 4.8$, and we can also see that

$$P_{42}/f_4 = 0.24$$

and

$$P_{52}/f_4 = 0.52.$$

By remembering that $P_{42} + P_{52} = 1$, we can solve these equations and obtain $P_{42} = 0.32$, $P_{52} = 0.68$ and $f_4 = 1.33$.

A6 stands out among the rim categories as having a much smaller f (f_4) than the others. While these rims are often smaller than those of other categories, this cannot be the whole explanation, and the category appears rather anomalous. However, the estimates of the coefficients in the equations (1) to (3) are not precise, so accurate estimates of the f's and g's cannot be expected. The basic equations were finally written as

$$
\begin{aligned}
Y_1 &= X_1 + X_2 \\
Y_2 &= \tfrac{1}{3}X_4 + X_5 \\
Y_3 &= X_3 + \tfrac{2}{3}X_4.
\end{aligned}
$$

The second stage [13] can now be divided into two parts:

(i) bowls and dishes (vessel categories A2B1 and A3B1)
and (ii) jars (vessel categories A4B3, A6B2, A6B3, and A7B2).

(i) the simplest relationship satisfying the available data can be written as

$$r_1 = 0.5q_1 - 0.8 \quad \text{(for A2B1)}$$

and

$$r_1 = 0.5q_2 - 0.8 \quad \text{(for A3B1)},$$

which we call hypothesis A. It was possible to vary the relationship while still satisfying

[13] All equations in this stage are given in inches.

the data, and a second hypothesis (B) was formed, representing the limit of acceptable deviation from A. The equations for B were

$$r_1 = 0.5q_1 - 1.5 \quad \text{(A2B1)}$$
$$r_1 = 0.5q_2 \quad \text{(A3B1)}.$$

Both hypotheses were carried forward to stage (iii), in the hope that the methods used there would indicate which was preferable.

(ii) for the jars, the simplest relationships satisfying all the data were:

$$r_2 = 0.5q_4 - 0.75 \quad \text{(A6B2)}$$
$$r_2 = 0.5q_5 - 0.75 \quad \text{(A7B2)}$$
$$r_3 = 0.5q_3 - 0.5 \quad \text{(A4B3)}$$
$$r_3 = 0.5q_4 - 0.5 \quad \text{(A6B3)}.$$

Little variation was possible in the first two equations, but it was found that the relationships expressed by the last pair could equally well be represented by:

$$r_3 = 0.5q_3 - 1.0$$

and

$$r_3 = 0.5q_4 + 0.5.$$

The former version of these equations was called hypothesis C, and the latter D. Both were carried forward to the next stage.

Reconstructions were made for all six vessel categories, all three sizes and all possible combinations of rim and base sub-categories. Hypothesis B was immediately ruled out, as it caused an unacceptable amount of distortion in some rim profiles, due to the projected base curve meeting the rim curve above its lowest actual point, which was thus left 'hanging'. It was also found that bowl and dish rims of sub-category (a)

TABLE 4: Diameters and heights of bowls and dishes (inches)

	category	*size*	*rim diameter*	*base diameter*	*height*
(a) dishes	A2B1(a)	25%	8.2	3.3	2.7
		50%	9.6	4.0	3.2
		75%	11.1	4.75	3.7
	A3B1(a)	25%	6.6	2.5	1.85
		50%	8.2	3.3	2.2
		75%	9.5	3.95	2.85
(b) bowls	A2B1(b)	25%	8.2	3.3	4.25
		50%	9.6	4.0	5.0
		75%	11.1	4.75	5.5
	A2B1(c)	25%	8.2	3.3	5.6
		50%*	9.6	4.0	4.75
		75%*	11.1	4.75	5.8
	A3B1(b)	25%	6.6	2.5	3.5
		50%	8.2	3.3	4.75
		75%	9.5	3.95	4.9

* with bases of sub-category (b).

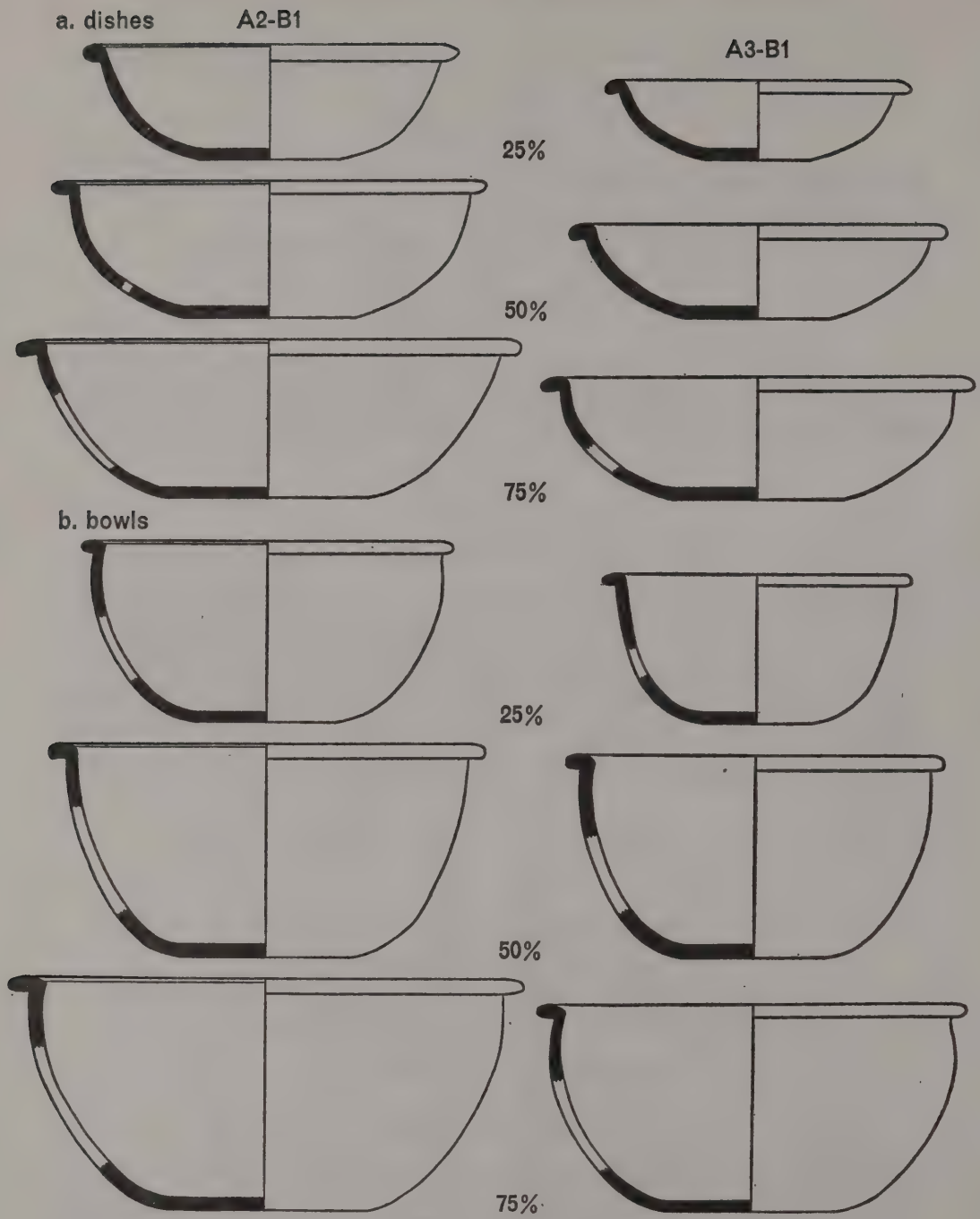


Fig. 7 Reconstructions of vessel categories A2B1 and A3B1 (¼ scale).

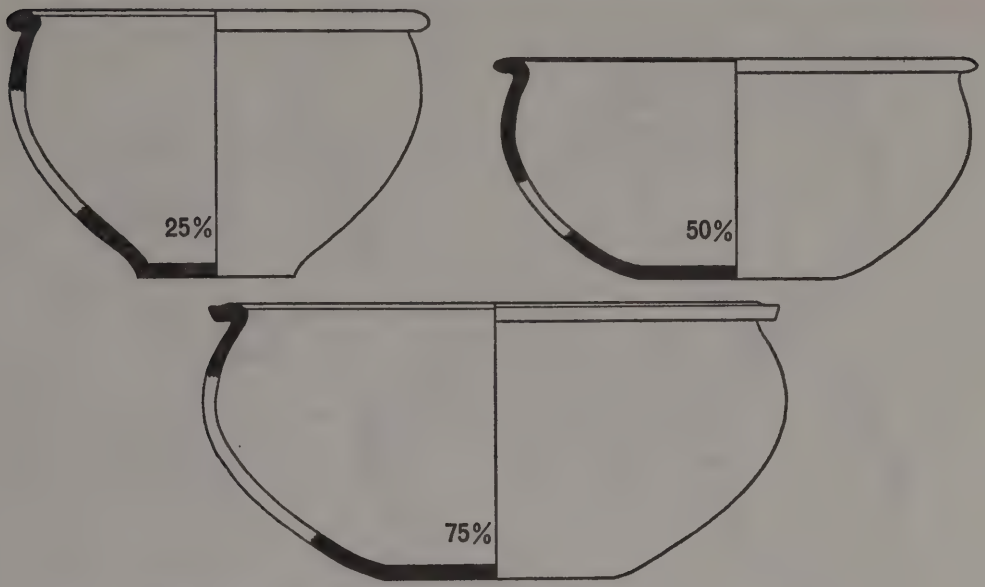


Fig. 8 Reconstructions of vessel category A2B1 (c) (¼ scale).

fitted with bases (a), rims (b) with bases (b) and rims (c) with bases (c) (for sizes where they existed) or (b). The reconstructed bowls and dishes are shown in Figs. 7 and 8.[14] Table 4 gives the rim and base diameters of these reconstructions, and their heights. Vessels of sub-category (a), with a height of about one-third of the diameter, are dishes on Webster's definition,[15] while vessels of sub-categories (b) and (c), with height of one-half of the diameter, or a little more, are bowls.

Reconstructions of the categories A6B2 and A7B2 followed. In both cases it was found that rims of sub-category (a) could not be fitted to bases (b), and therefore must have (a) bases. The (b) bases must therefore belong to (b) rims, and we can speak of two sub-categories of vessel: (a) with broad shoulder and a convex base, and (b) a streamlined form with a concave base. The successful reconstructions are shown in Figs. 10 and 11, and the rim and base diameters and heights in Table 5.

The categories A4B3 and A6B3 gave the most difficulty, as there was the added complication that hypothesis C might hold for one sub-category and hypothesis D for the other. As above, the combination of (a) rims and (b) bases was ruled out, leaving two vessel sub-categories, (a) and (b). There was no overwhelming mathematical evidence in favour of either hypothesis, but a comparison of the reconstructions with known vessels seemed to favour C, which was therefore adopted (it had the

[14] In all drawings of reconstructed vessels, the solid parts of the section are the original sherds, and the hollow part is reconstructed.

[15] Webster, G. (ed.) *Romano-British coarse pottery: a student's guide*. CBA Research Report no. 6. (London, 1964), p.9.

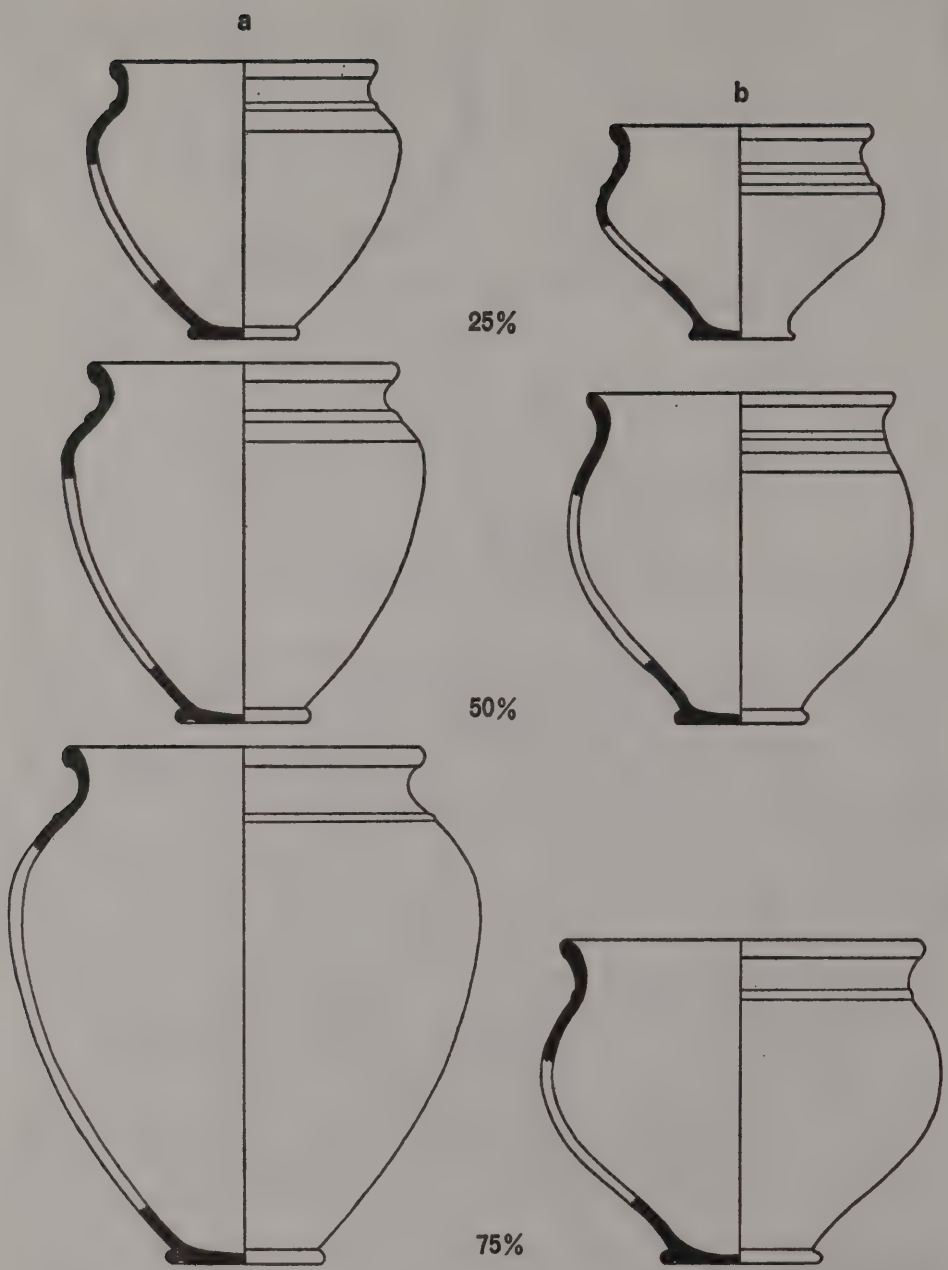


Fig. 9 Reconstructions of vessel category A4B3 (¼ scale).

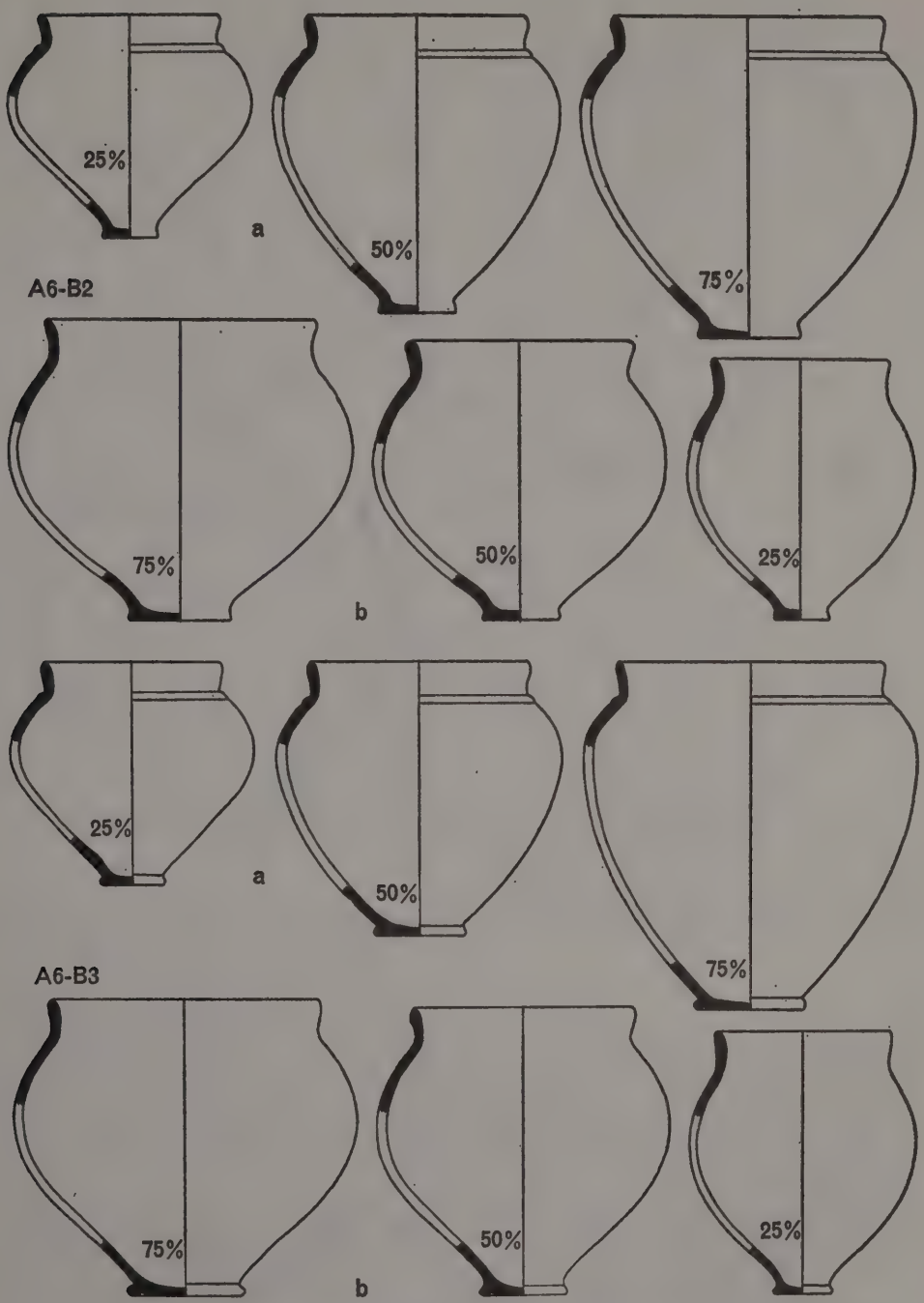


Fig. 10 Reconstructions of vessel categories A6B2 and A6B3 ($\frac{1}{4}$ scale).

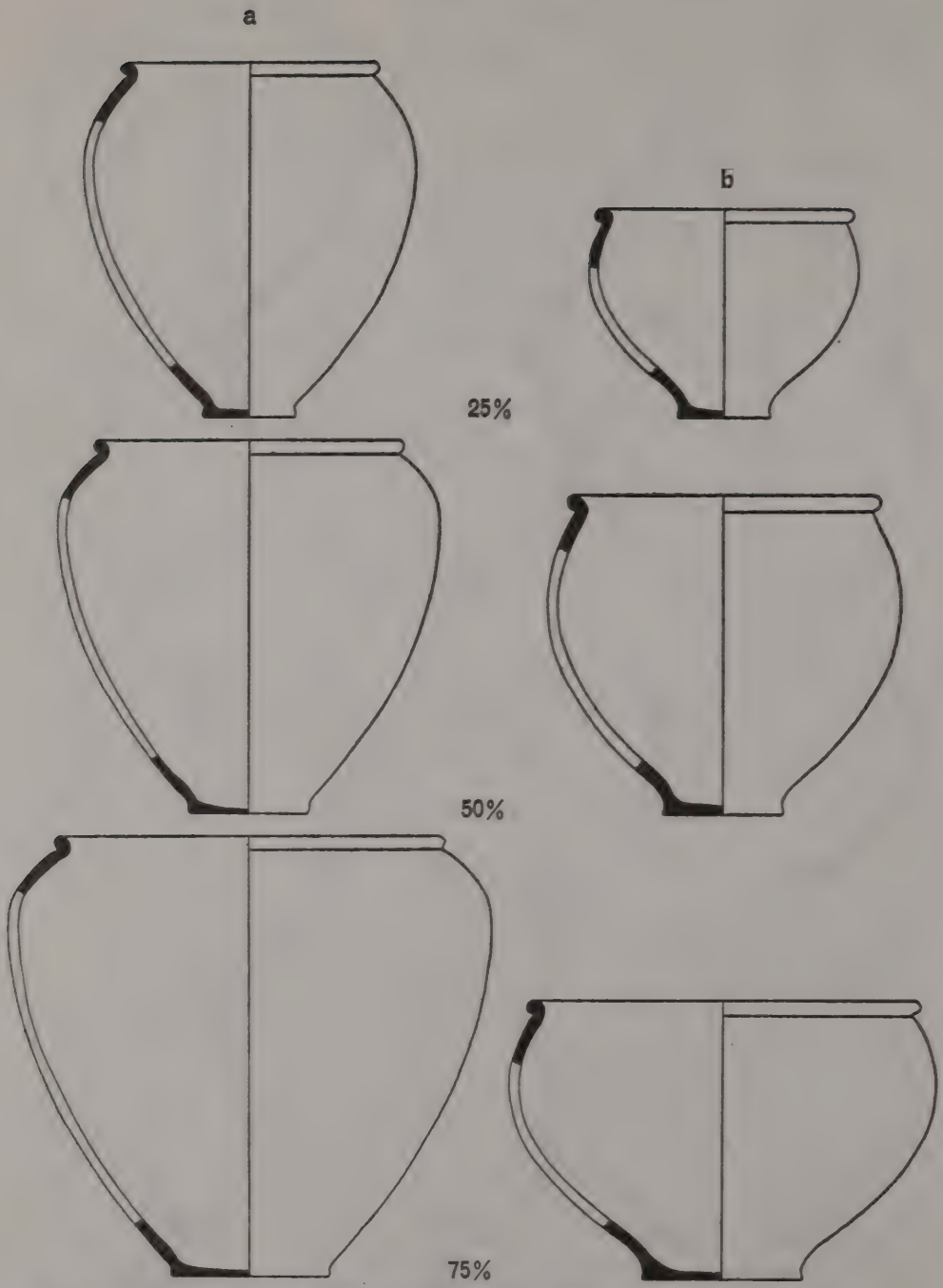


Fig. 11 Reconstructions of vessel category A7B2 (¼ scale).

TABLE 5: Diameters and heights of jars with bases of category B2 (inches)

	category	*size*	*rim diameter*	*base diameter*	*height*
(a) 'broad' vessels	A6B2(a)	25%	4.2	1.35	5.4
		50%	5.2	1.85	7.2
		75%	6.4	2.45	7.8
	A7B2(a)	25%	5.7	2.1	8.1
		50%	7.0	2.75	8.6
		75%	8.8	3.65	10.2
(b) 'slim' vessels	A6B2(b)	25%	4.2	1.35	6.3
		50%	5.2	1.85	6.75
		75%	6.4	2.45	7.25
	A7B2(b)	25%	5.7	2.1	4.8
		50%	7.0	2.75	7.3
		75%	8.8	3.65	6.5

TABLE 6: Diameters and heights of jars with bases of category B3 (inches)

	category	*size*	*rim diameter*	*base diameter*	*height*
(a) 'broad' vessels	A4B3(a)	25%	5.4	2.2	5.8
		50%	6.3	2.65	7.5
		75%	7.4	3.2	10.8
	A6B3(a)	25%	4.2	1.6	5.4
		50%	5.2	2.1	6.6
		75%	6.4	2.7	8.4
(b) 'slim' vessels	A4B3(b)	25%	5.4	2.2	4.45
		50%	6.3	2.65	6.9
		75%	7.4	3.2	6.75
	A6B3(b)	25%	4.2	1.6	6.4
		50%	5.2	2.1	7.0
		75%	6.4	2.7	7.2

added claim of being the simpler solution). Figures 9 and 10 show these reconstructions, and Table 6 their dimensions.

6. *Archaeological conclusions*

The production of the site was concentrated on six categories of sand-tempered vessels—A2B1, A3B1, A4B3, A6B2, A6B3 and A7B2, with possibly a seventh (A7B1), which is predominantly a grog-tempered category. In all categories the base diameter is about half the rim diameter, less a 'constant' which varies from category to category. Within each category there are two sub-categories, representing bowls and dishes in A2B1 and A3B1, and squat and slim jars in the other categories. There is considerable variation about the most common sizes, and it has been suggested that part of this variation was deliberate.[16] The estimates of 'brokenness' could be used to derive

[16] op. cit. fn. 6, p. 350.

estimates of the proportion of the waster output represented by each category. Such estimates would not be very reliable, and would in any case be of limited value because they would relate only to waster output and not to production. The major outstanding problem is to relate proportions of categories in the wasters to proportions in the actual production. Other problems include the relating of detailed differences in rim form to vessel category and size.

7. *Discussion*

The project succeeded in its main aim of reconstructing the waster pottery from the site, but a number of questions remain unanswered. Ideally, far more lots should have been used (in this context, nine or even twelve lots is a very small sample). Given the limited area of the waster dumps, this could have best been achieved by recording in smaller units within each trench—perhaps 1- or 2-metre squares. The ideal unit would be the smallest for which the models of stage (i) still hold, but experiments would be needed to determine it. Further work is also needed to discover the most suitable form for the equations used to represent the vessel profiles: quadratics were used because of their extreme simplicity, but they have disadvantages—for example their sensitivity to small errors in drawing or transferring the drawings to paper tape, and their relative inflexibility.

It was suggested that, in view of the small value of f_4 in comparison with the other f's a better result might be obtained by omitting the category A6B2 altogether. This would certainly improve the f's as a whole, but at the expense of a very large chi-squared statistic for the B2 bases. The nature of the model tends to throw much of the random error into the f's and g's, so large fluctuations in them should not be taken too seriously.

The uses of the techniques described here are restricted: they are really only suited to material from large waster dumps. Also, if a large proportion of the wasters were complete vessels, the techniques would be superfluous. Before such a project can be carried out, much preparatory work must be done, in sorting, classifying, measuring and drawing the sherds. While this work should always be done, it is clear that the project is no 'short cut'. Its advantages lie more in the reduction and presentation of the data—the entire mass of wasters can be described in about fifty drawings. None of them are of actual vessels, but together they represent the entire range of vessels in production, and overcome the problem that the few complete vessels may not be representative. It is hoped that the methods and results presented here will encourage other archaeologists, not to repeat this exercise, but to experiment with similar model-building and testing approaches to their own problems.

8. *Summary*

A problem facing the excavator of a kiln site is that of reconstructing the pottery found in order to describe the production of the kilns. There is often a very large quantity of material to be dealt with, and at the 1st to 2nd century Romano-British

kiln site of Highgate Wood, London, the problem was complicated by the fragmentary nature of the pottery from the waster dumps and elsewhere.

An alternative approach to the physical reconstruction of vessels is presented. By using statistical models of the relationships between rim and base sherds, and geometric models of vessel forms, reconstructions can be made mathematically on the basis of a simple empirical classification of rim and base forms. Vessel categories are an outcome of the reconstruction process, in that no further classification is needed. The waster output of the site can be described in terms of a scheme of hypothetical vessels, which taken as a whole give a complete picture of the bulk of the output.

Two advantages are claimed for this approach: (i) it enables the reconstruction of vessel forms to be carried out on very fragmentary material, an otherwise impossible, or at least enormous, task, (ii) it enables the waster output to be described efficiently and effectively.

9. *Acknowledgments*

Thanks are due to A. E. Brown and H. L. Sheldon for allowing me to use data from their excavations, and to the adult students at the City Literary Institute, London, who have sorted, measured and drawn much of the pottery. The opinions expressed in this report are, however, entirely my own. A computer terminal linked to a GE265 computer was supplied to the author free of charge for a year (July 1970 to July 1971) by Honeywell Information Systems Ltd and *New Scientist* magazine. Computer and exchange line time were also free, within a limit of £1000.

I also wish to thank Dr. F. R. Hodson of the Institute of Archaeology for his encouragement during the project and his comments on the manuscript of this report.

Metal Analyses - their limitation and application to the Early Bronze Age in Ireland *

by BARBARA CLAYTON

Factors affecting the final composition of the metal artifact

Throughout its history a metal artifact is subjected to various processes which can affect the final composition of the object today, and hence its analysis. These variable factors include—the ore itself, the smelting of the ore, alloying with other metals, conditions of casting, subsequent work on the casting, its immediate environment up to the time of analysis and the actual analysis itself.

Ores

Any ore contains, as well as the main metal (in this case copper), other elements either physically mixed or in chemical combination with this metal. These elements, the trace elements, can vary in quantity from ore deposit to ore deposit and also within one deposit. This is due in part to the varying conditions under which ore deposits can be formed.[1] For example, on the south side of Mount Gabriel, Co. Cork, the copper deposits were laid down at the same time as the rock in which they are found, while on the north side of the same mountain, a more recent deposit has been formed by the infilling of fissures in the already formed rock by a copper bearing solution.[2]

The composition of an ore can also be altered by the way in which it is affected by weathering. For example, in Chalcopyrite ores, the copper content of the surface deposits will be washed down and deposited in the lower layers, causing secondary enrichment of those layers. The passage of ground-water through the deposit can lead to the addition and subtraction of trace elements. Depending on the drainage system, trace elements can be brought in this way from other completely different deposits.

[1] J. F. Kirkaldy, *Minerals and Rocks*, London 1968, 91 f.

[2] J. S. Jackson, 'Bronze Age Copper Mines on Mount Gabriel, West Co. Cork, Ireland', *Archaeologia Austriaca* 44 (1968), 93.

* This paper was written as a dissertation presented for the B.A. degree at the Institute of Archaeology, July, 1971.

A comprehensive series of analyses of all the known copper ores, particularly those known to have been used by prehistoric metallurgists, taking a number of samples from varying depths from each deposit, and where known each mine, should show whether there is any pattern within the trace elements which could be used to distinguish ores, either on a regional or deposit basis. By taking several samples from each deposit, it should be possible to test the significance of the proportions of various elements within that deposit, and hence assess the usefulness of these proportions in distinguishing regional variations and variations from deposit to deposit.

Although there are over 100 analyses available of Irish copper ores, it is by no means possible to do this with them. The majority are taken from museum samples and little is known about their provenance. Occasionally the name of the mine is given, but more often the name of the village or townland. This means, that for many analyses, it is not possible to specify the deposit, since several deposits could be covered by the given provenance. For example, as has been shown at Mount Gabriel, copper deposits of different origins, and possibly different composition, can occur very close together. In the same region, due to faulting, what is essentially the same deposit is found in three different townlands.[3] Most analyses of ores can however be related to the main ore-bearing regions, as shown in Fig. 1. Also, from this map, it can be seen that the analyses available are in no way representative of the ore-bearing regions known, and a few are from areas where there is no known ore deposit.[4]

There is little evidence of early mining in Ireland, and what there is cannot generally be securely dated. Most of the evidence is from small workings which have produced stone mining-mauls, which could date from the Early Bronze Age, but are just as likely to be of any date up to and including the Early Christian Period.[5] These mines are mainly found in the south-west of Ireland.

Possible examples which can be given a more precise date include those which are known to have been buried by peat. The growth of a peat cover had begun in most areas by *c.* 500 BC. The mines should therefore have been worked at a date prior to this, i.e. during the Bronze Age.[6]

At Ballyrisode (=Ballyrizard), Co. Cork, polished stone axes were found in a mine the entrance of which had been sealed by a roof fall. The manufacture of polished stone axes had virtually ceased by the Iron Age, therefore it is inferred that the mining activities were prior to this date.[7]

At Mount Gabriel, Co. Cork, some mines are known to have been buried by peat. Some excavation was carried out at one of the mine sites by Jackson and Raftery in

[3] *loc. cit.* 93 and fig. 2.

[4] The analyses referred to are from H. H. Coghlan, J. R. Butler, G. Parker, *Ores and Metals*, Royal Anthr. Inst. Occ. Paper 17 (London, 1963), 40 f.; H. H. Coghlan and R. F. Tylecote, 'Analyses of Copper Ores', *Bull. of Hist. Metallurgy Group* 4, 2 (1970), 80; and H. H. Coghlan and H. J. Case, 'Eary Metallurgy of Copper in Ireland and Britain', *P. P. S.* 23 (1957), 122.

[5] O'Kelly quoted in P. Harbison, 'Mining and Metallurgy in Early Bronze Age Ireland', *North Munster Antiquarian Journal* 10 (1966), 5.

[6] Jackson, *op. cit.* fn. 2, 100 and Harbison, *op. cit.* fn. 5, 3.

[7] Jackson, *op. cit.* fn. 2, 99 and Harbison, *op. cit.* fn. 5, 4.

Figure 1 The main copper ore deposits of Ireland

An asterisk indicates that samples from that deposit have been analysed. The accompanying figure is the number of analysed samples from that deposit. The figures in circles indicate the number of analyses that have not been located to ore deposits of the county concerned. (Ore deposits after P. Harbison, 'Mining and Metallurgy in Early Bronze Age Ireland', *North Munster Antiquarian Journal* 10 (1966) 5).

1966. A sample of charcoal was taken from two layers separated by a sterile layer consisting of ' "fines" with some angular sandstone fragments'. This sample gave a date of 1500 ± 120 BC (VRI—66)[8]. Although this *one* date is from a mixed sample it might perhaps be possible to infer that the mine was in use by then and possibly earlier.

Smelting

The method used to smelt the ore is very important when considering the final composition of the metal. The processes employed can dictate to some extent which, and in what proportion, trace elements are likely to be transferred to the metal.

Oxide ores need only to be smelted with charcoal to be reduced to copper. The more complex sulphide ores have to be roasted to convert their high content of iron sulphide to oxide so that the iron finds its way more readily to the slag during smelting.

The easiest way to roast the ore would be to heat it in a pile. There are various factors which could affect the outcome of this process. These include the manner of packing and venting the pile. Standard procedures in these matters could lead to a fairly standard product. There is however one factor which affects the outcome of the process that is impossible to standardise. This is the weather. For example, the direction and speed of the wind will alter the temperature of the fire and thus the result of the roasting. Different ways of packing the ore can compensate to some extent for wind direction, but not for speed. Without some form of bellows it would therefore be difficult to control the temperature of the roast. No bellows are known from this period. There are however no workshop sites known of an early bronze age date.

During roasting, sulphur, arsenic (highly volatile, particularly in its oxide form), antimony and various other elements will be modified in quantity.

During smelting the reactions are highly complex. Most copper ores, particularly sulphide ores, contain a high proportion of iron. To remove this the furnace temperature must be sufficiently high to produce liquid slag and metal, i.e. above the melting point of copper which is 1083°C. This is above the temperature obtained from an open fire, therefore some artificial means of raising the temperature, e.g. a forced draught as used in most pottery kilns, must have been used from an early date.

Whether certain elements stay in the metal or are lost in the slag depends on the temperature of the furnace and other variables which alter the partition coefficient between the slag and the metal. Arsenic, antimony, gold, silver, tin, nickel, lead and bismuth are retained in the copper under normal smelting conditions. Under stronger reducing conditions, manganese and cobalt will be retained in the metal. Arsenic, because it is highly volatile (it sublimes at 400°C), is modified considerably in quantity during the smelting. Zinc, cadmium and phosphorus could be reduced in quantity in this way, as can antimony and bismuth to some extent and possibly lead.

The composition of the smelted metal therefore will be dependent on the smelting process used. Standard practices could yield a fairly standard result. However, under

[8] Jackson, *op. cit.* fn 2, 98–99. Jackson quotes a date of 1270±90 BC. This date is given as 1500±120 BC in *Radiocarbon* 12 (1970), 316 VRI—66.

primitive smelting conditions, the weather again plays a considerable part in controlling the temperature of the furnace and so affects the proportions of the trace elements retained in the copper.

The fact that a metal of uniform composition was obtained, as shown here in figures 3, 4, 7 and 9, and by Hodson[9] shows that standard procedures were followed by workshops or groups of workshops, and that the weather must have been taken into account.[10]

Alloying with other metals

When copper was alloyed with other metals (during the Early Bronze Age tin and arsenic) the addition of these other metals led to the inclusion of the trace elements in them in the final copper alloy. Varied sources and varied preparation of the arsenic and tin could lead to variations in their composition. This, and the different ways in which the arsenic and tin could be added to the copper, could lead to variations in the composition of the alloy. However the analyses under consideration here show little variation if any in the composition of the artifacts due to the addition of these elements.

Casting and Subsequent working

During casting certain elements within the molten metal can be oxidised if exposed to the atmosphere. In their oxide forms these are present as inclusions rather than being alloyed with the copper. This oxidisation can be avoided by 'poling' the molten metal, or by covering it with charcoal during melting in a crucible, so producing a reducing atmosphere. In an open mould, the upper surface of a cooling metal would be oxidised unless this was prevented by covering the mould with, for example, a stone or charcoal.

Any subsequent hot working or annealing of the artifact could lead to the loss of volatile elements, e.g. arsenic and phosphorus. An arsenical copper need only be heated to *c.* 300°C to anneal it, but if tin is present as an alloy then a higher temperature is required, the actual temperature depending on the percentage of tin.[11] Arsenic, particularly in its oxide form, is likely to be lost. (The oxide sublimes at 200°C, the metal at 400°C.) The amount of arsenic lost will depend on the temperature reached in the annealing and for how long the process was continued.

The environment of the artifact

The conditions under which the artifact is preserved will affect the composition of the metal. Corrosion alters the outer layers of the metal, and these areas should be avoided when taking samples for analysis. However, although it can be seen that only

[9] F. R. Hodson, 'Searching for Structure within Multivariate Archaeological Data', *World Archaeology* 1 (1969), 97–105.
[10] H. H. Coghlan in H. H. Coghlan, J. R. Butler and G. Parker, *Ores and Metals*, Royal Anthr. Inst. Occ. Paper 17 (London, 1963), 1 f.; H. F. Tylecote, *Metallurgy in Archaeology* (London, 1962), 15 f.
[11] Tylecote, *op. cit.* fn. 10, 49.

part of the metal has been chemically altered by corrosion, it is not known to what extent and depth the trace elements could be affected by the immediate environment of the artifact before the main body of the metal is attacked by corrosion. For example, many of the objects listed here (Tables I–IV,) were found in peat. It is not known what effect the ground water could have on these artifacts. It might remove trace elements but might also add others.

The analysis

The position of the sample taken for analysis can affect the result. As has been suggested above, areas of corrosion are avoided wherever possible. This can be difficult if the object is very badly corroded or if the object is thin: e.g. sheet metal work, some daggers and trinkets such as No. 202, Table III.

The composition of the metal can vary within one artifact. Some elements are alloyed with the copper and should be evenly distributed. These include gold, silver, arsenic, antimony, cadmium, zinc, tin, nickel, cobalt and phosphorus. Any oxides present, and bismuth, lead and iron are found as inclusions and are therefore unevenly distributed throughout the metal. A sample could therefore be deficient in or have a too high proportion of these elements. However, samples may be large enough to overcome this problem, or the average result of analyses performed on several samples may eliminate the unevennesses.

Slater and Charles[12] have shown that on cooling there is some segregation of bismuth and lead in castings, thus emphasising the uneven distribution to a greater degree. Richards and Blin-Stoyle[13] have shown that the variations in composition within an artifact are not as great as the variations between different analysts. Any method of comparing analyses carried out by different analysts should therefore allow for this fact.

The results of comparing the analyses of the artifacts listed in Tables I–IV, show that the variable factors discussed above, and any others that have not been included, were sufficiently controlled and the weather sufficiently understood by the prehistoric metallurgists, to produce on the whole a product of a reasonably uniform composition. Since things would not always go quite as planned, particularly as the weather in Ireland can be as unpredictable as it is in the rest of the British Isles, a few objects whose composition varies a little from the majority would not be surprising. What is perhaps unexpected is that there are in fact very few such objects.

Interpretation of the analyses

The method used here for comparing the analyses is that devised by Waterbolk and Butler.[14] This method eliminates to some extent the significance of the variations

[12] E. A. Slater and J. A. Charles, 'Archaeological Classification by Metal Analyses', *Antiquity* LXIV (1970).
[13] E. E. Richards and A. E. Blin-Stoyle, 'A Study of the Homogeneity in Composition of an Irish Thick-butted Axe', *Archaeometry* 4 (1961), 53 f.
[14] H. T. Waterbolk and J. J. Butler, 'Comments on the use of Metallurgical Analyses in Prehistoric Studies', *Helinium* 5 (1965), 227–251.

in the results of different analysts by placing each analysis result for each element in a group defined by a percentage range which, it is hoped, is large enough to mask this variation but not so large as to eliminate any variations due to the actual composition of the artifact. The 'very low' range of Waterbolk and Butler has been omitted here because the limit of detection of some of the analysts is higher than the lower values included in this range. This was done by Case[15] and Coles[16].

The analyses have been split into four groups depending on the type of alloy. These groups are—

Unalloyed copper (Table I and fig. 3);

Copper alloyed with arsenic (Table II and fig. 4);

Copper alloyed with arsenic and tin (Table III and fig. 7);

Copper alloyed with tin (Table IV and fig. 9).

According to Charles [17] an arsenic content of more than 0.5% indicates that some deliberate addition of arsenic has been made. Whilst compiling the histograms (figs. 3, 4, 7 and 9), it became apparent that certain objects with less than 0.5% arsenic appeared to belong to the group alloyed with arsenic rather than with those that were unalloyed or alloyed only with tin. These are included in the groups of metal alloyed with arsenic.

As can be seen from the map (fig. 2), the distribution of the objects analysed is not even. There are concentrations in the north and south-west with a smaller concentration in the eastern central region. This distribution reflects the distribution of associated finds.[18] Axes have a similar distribution,[19] the northern group however being more pronounced and less distinct from the central group. Halberds and daggers are confined more to the northern and particularly the central groups and are poorly represented by comparison with the overall distribution of artifacts in the south-west.[20] The analysed halberds and daggers show a similar distribution.

Since many of the provenanced artifacts have been found during peat cutting the distribution of peat and areas where it is and was cut could affect the distribution of the artifacts, as could the possible unevenness of archaeological activity.

The distribution of analysed objects is, as has been shown above, similar to the distribution of metal artifacts of this period. On the grounds of distribution therefore the analysed objects can be considered as a representative selection.

Halberds and daggers are of a similar form and in some cases the dividing line between the two types can be hard to distinguish; witness the disagreement over

[15] H. J. Case, 'Were the Beaker-People the first Metallurgists in Ireland?', *Palaeohistoria* XII (1966), 164 f

[16] J. M. Coles, 'Metal Analyses and the Scottish Early Bronze Age', *P. P. S.* 35 (1969), 330-343.

[17] J. A. Charles, 'Early Arsenical-Bronzes—a Metallurgical View', *American Journal of Archaeology* (1967), 21–26.

[18] P. Harbison, 'Catalogue of Irish Early Bronze Age Associated Finds containing Copper or Bronze', *Proc. of the Royal Irish Academy* 67C (1968–69), 40.

[19] P. Harbison, *The Axes of the Early Bronze Age in Ireland*, Prähistorische Bronzefunde IX.I (Munich, 1969), Pls. 79 and 80.

[20] P. Harbison, *The Daggers and Halberds of the Early Bronze Age in Ireland*, Prähistorische Bronzefunde VI.I (Munich, 1969), Pl. 25.

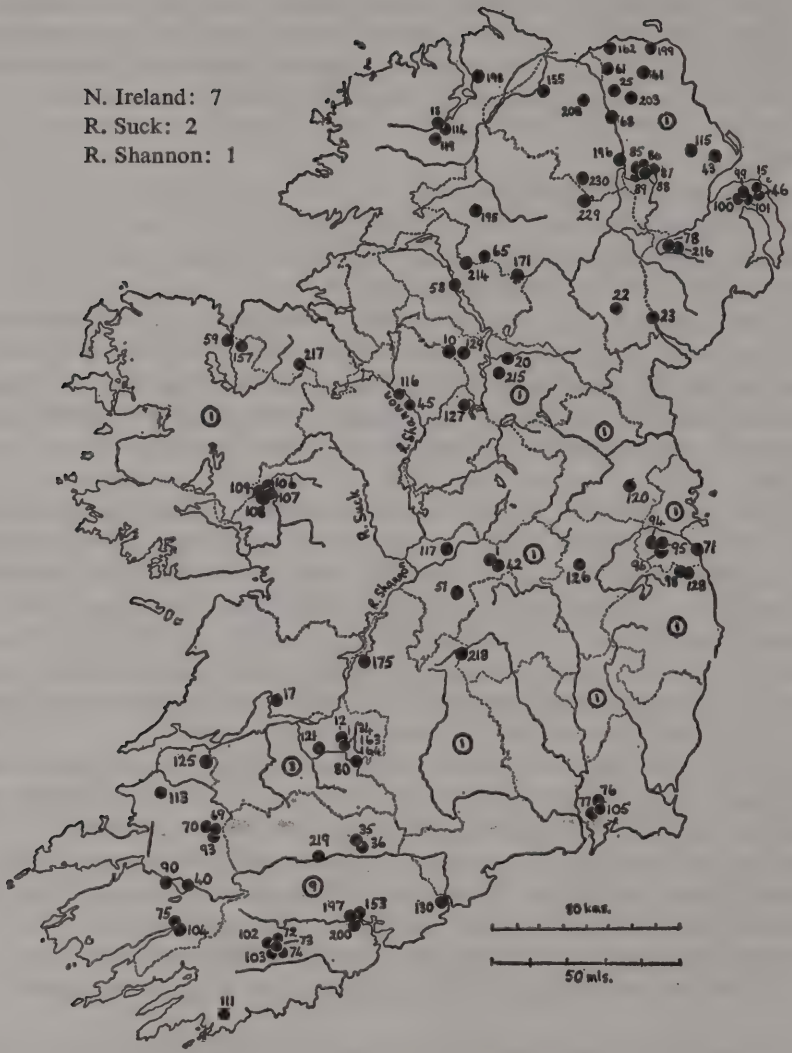


Figure 2 The distribution and location of find spots of analysed objects with provenance other than 'Ireland'

Numbers in circles indicate the number of analysed objects whose provenance is limited to the county only. Other numbers are those given to the objects as listed in Tables I–IV.

whether one of the 'daggers' from Whitespots, Co. Down, is in fact a halberd or dagger (Table II. No. 100)[21]. Halberds and daggers can therefore be considered together as a group as opposed to axes.

Using the figures obtained from Harbison[22] as representing the total numbers of axes and halberds and daggers of this period, there are proportionally fewer axes analysed than halberds and daggers. Within the halberds and daggers, there are fewer analysed daggers in proportion to analysed halberds than there are daggers to halberds. 14% of the total number of axes, daggers and halberds are halberds and daggers, and of these 55% are halberds. However, 36% of the analysed objects are halberds and daggers and of these 80% are halberds. Provided that each group of analysed objects is a representative selection for that group these differences should not affect the final result significantly.

Of the 54 analysed halberds that can be assigned to types, 20% are of type Carn, 57% of type Cotton, 11% of type Clonard and 11% of type Breaghwy. Using figures obtained from Harbison[23] of the total number of halberds, 27% are of type Carn, 51% of type Cotton, 14% of type Clonard and 8% of type Breaghwy. The analysed halberds can therefore be considered to be a representative selection.

There are only 15 daggers analysed and for only two of these is the type known; therefore no check can be made to see if they are a representative selection.

Of the 160 analysed axes, 89 can be assigned to types. Of these, 33% are of type Lough Ravel, 6% of subtype Ballybeg, 11% are 'ingots', 17% are of type Killaha, 22% are of type Ballyvalley and 10% are of type Derryniggin. Using the numbers for these types obtained from Harbison[24] of the total number of axes, 17% are of type Lough Ravel, 5% of subtype Ballybeg, 3% are 'ingots', 15% are of type Killaha, 42% are of type Ballyvalley and 16% are of type Derryniggin. This appears to be a less representative selection than that of the halberds.

Classified according to Case's typology[25] 30% of the analysed axes are of thick-butted type, 47% are thin-butted and 22% are hybrids. There are however no figures according to this typology for the total number of axes with which to compare these percentages to see if they are a representative selection.

Harbison[26] divides the Early Bronze Age into five phases as follows—

I Knocknague: Lough Ravel axes and Knocknague daggers

II Frankford: Subtype Ballybeg axes, halberds of types Carn, Cotton and Clonard and daggers of type Corkey

III Killaha: Axes of type Killaha and halberds of type Breaghwy

[21] *Archaeological Survey of Co. Down* (Belfast, 1966), 25; P. Harbison, *op. cit.* fn. 18, 58; H. J. Case, *op. cit.* fn. 15, 163.
[22] Harbison, *op. cit.* fns. 19 and 20.
[23] Harbison, *op. cit.* fn. 20.
[24] Harbison, *op. cit.* fn. 19.
[25] Case, *op. cit.* fn. 15.
[26] Harbison, *op. cit.* fn. 18, 61; P. Harbison, 'The Relative Chronology of Irish Early Bronze Age Pottery', *Journal of the Royal Society of Antiquaries of Ireland* 99 (1969), 63 f. and fig. 1.

IV Ballyvalley: Axes of type Ballyvalley
V Derryniggin: Axes of type Derryniggin

Bronze appears in phase III.

Harbison's 'ingots' are roughly contemporary with his type Lough Ravel and subtype Ballybeg axes, i.e. in phases I and II.[27]

Case[28] divides the same period into three main phases as follows—

1. Archaic phase—Thick-butted axes
2. subdivided into two—
   a. Impact phase—marked by innovations brought by the Beaker people, including the introduction of tin bronze, tanged daggers, daggers with rivetted tangs, daggers with rivet notches, thin-butted axes and the first halberds, and hybrid axes
   b. Thin-butted axes, including bevelled axes (a hybrid type), the first decorated axes, most halberds, and daggers related to the Bush Barrow type. Contemporary with the first phase of the Wessex Culture
3. The final phase of the Early Bronze Age corresponding to the second phase of the Wessex Culture

According to Apsimon,[29] the two chronologies can be correlated as follows—

Harbison		Case
phase I	=	Archaic phase, 1, and initial Impact phases
phase II	=	Impact phase, 2a, and some innovations from the beginning of 2b
phase III	=	Developments and innovations of phase 2b
phase IV	=	phase 2b
phase V	=	phase 3

Unalloyed copper

Table I (see page 106); fig. 3

There are only 7 objects in this group. Of these, 4 have provenance given as 'Ireland', 1 as 'Co. Cork', 1 as 'Co. Dublin' and 1 from Trillick, Co. Tyrone. It is therefore impossible to consider their distribution. Little can be said about the composition of the metal because of the small number of objects in this group. Arsenic and tin are either not detected or present as a trace.

The objects themselves are 6 axes and 1 halberd rivet from a type Carn halberd. Rivets are generally considered to be of softer metal than the rest of the halberd or dagger. Unalloyed copper is softer than when alloyed with either tin or arsenic and it is perhaps surprising that more rivets are not of unalloyed copper.[30] The types of 5 of the 6 axes are known. According to Harbison's classification, 2 are 'ingots',

[27] Harbison, *op. cit.* fn. 19, 83.
[28] Case, *op. cit.* fn. 15.
[29] A. M. Apsimon, 'The Earlier Bronze Age in the North of Ireland', *Ulster Journal of Archaeology* 31 (1969), 28–72.
[30] Only 5 rivets have been analysed. The other 4 are of copper alloyed with arsenic.

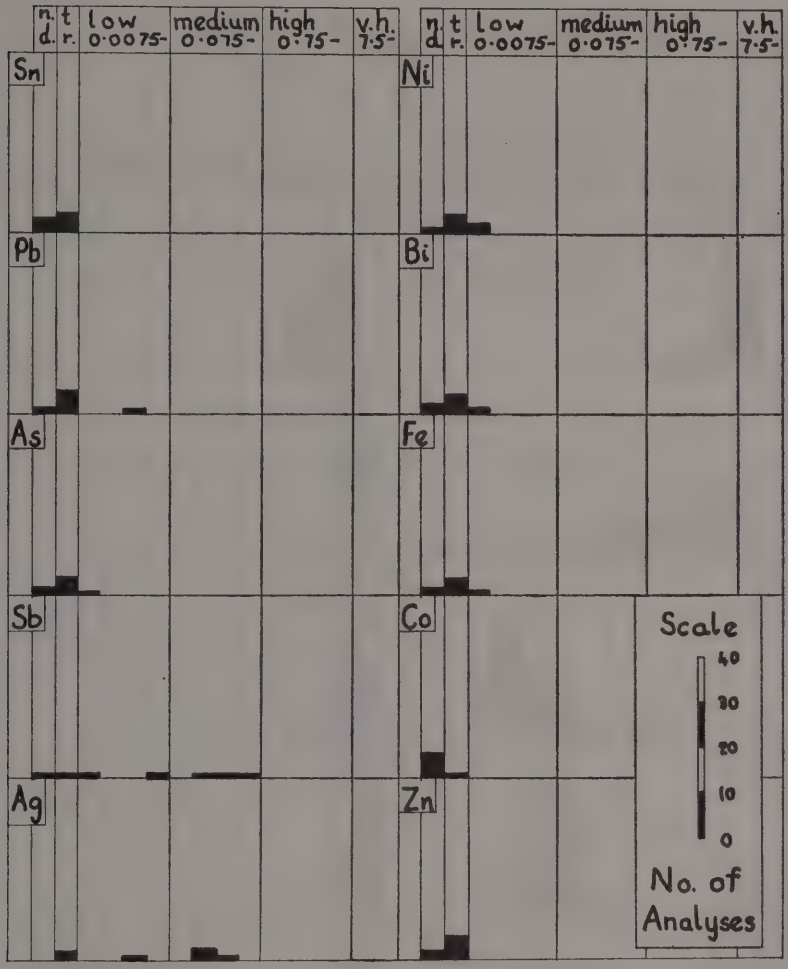


Figure 3 The composition of objects of unalloyed copper

Total number of analyses=7

n.d.=not detected; tr.=trace

low=0.0075–0.075%

subdivisions 0.0075 – 0.013%
0.013 – 0.024%
0.024 – 0.042%
0.042 – 0.075%

medium=0.075 – 0.75%

subdivisions 0.075 – 0.13%
0.13 – 0.24%
0.24 – 0.42%
0.42 – 0.75%

high=0.75–7.5%

subdivisions 0.75 – 1.3%
1.3 – 2.4%
2.4 – 4.2%
4.2 – 7.5%

v.h.=very high=7.5 – 24%

subdivisions 7.5 – 13%
13 – 24%

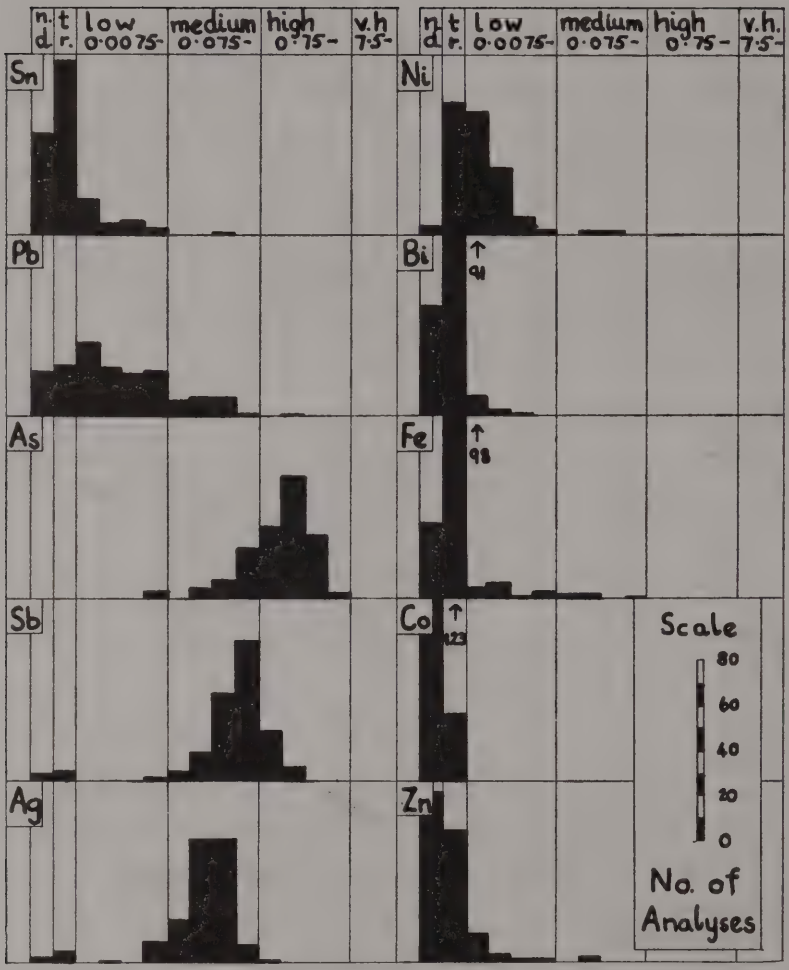


Figure 4 The composition of objects alloyed with arsenic
Total number of analyses = 153. *For information on subdivisions see figure 3.*

2 are of type Lough Ravel and 1 is of subtype Ballybeg. According to Case's typology, 3 are anomalous, 1 is thick-butted and 1 is hybrid. The objects in this group belong to Harbison's phases I and II, Case's phases 1 and 2a.

The ranges of the percentages of the elements are not outside those found in the other groups discussed here. As will be seen later it is possible to subdivide the groups of metals on their antimony and silver content. In this group the sub-group with low antimony would include No. 62, the halberd rivet, No. 63, an axe of subtype Ballybeg, both from 'Ireland' and No. 204, an anomalous axe or 'ingot' from 'Co. Dublin'. The sub-group with a low silver content would include No. 204 mentioned above as having a low antimony content and No. 66, an 'ingot' from 'Co. Cork'.

Copper alloyed with arsenic

Table II (see page 107); figs. 4, 5, 6.

Of the 153 analyses in this group, Nos. 34, 163, 164 and Nos. 132, 140 are different analyses of the same axes. Four of the analyses are of rivets from halberds which have also been analysed. There are therefore 146 objects in this group. Of these 47 have provenance given as 'Ireland', 7 are from 'N. Ireland', 2 are from the 'R. Suck', 1 is from the 'R. Shannon', 12 have provenance given as a county and 77 have a more precise provenance. The distribution of these 77 objects shown on fig. 6 closely follows the distribution of all the analysed objects (fig. 2).

Of these 146 objects, 88 are axes, 57 halberds and daggers, and one a piece of smelted copper. Thirty-eight of the axes and 47 of the halberds and daggers can be assigned to types. According to Harbison's typology, 10 of the halberds are of type Carn, 27 of type Cotton, 7 of type Clonard, 1 of type Breaghwy, 1 similar to type Breaghwy and 1 miscellaneous. The axes include one double axe, No. 152, 28 of type Lough Ravel, 2 of sub-type Ballybeg, 1 of type Killaha, 1 of type Ballyvalley; 7 are 'ingots'. According to Case's typology, 21 are of thick-butted type, 9 are of hybrid form, 3 of thin-butted type and 6 anomalous. These would fall within Case's phases 1 and 2a, Harbison's phases I and II. The halberds are generally later than the earliest axes in the group which are of thick-butted type or type Lough Ravel.

From fig. 5 it can be seen that the composition of the halberds and daggers is very similar to that of the axes but with several slight variations. In halberds and daggers as opposed to axes tin is recorded in a higher percentage as not detected but in a lower percentage as a trace. Although the peaks for arsenic of all three coincide there are proportionally more halberds and daggers with a higher percentage of arsenic than there are axes. A similar picture to this but less marked is obtained for antimony. The silver content of the two groups is similar but some halberds and daggers have a higher silver content than any of the axes. These are Nos. 1, 3, 6, 7, 8, 9, 56, 118 and 146.

Axe No. 67 is anomalous in composition due to its higher content of tin. Its iron content, though not sufficiently different to be considered anomalous, is nevertheless

Figure 5 The comparative composition of axes (————), halberds and daggers (– – – – –) of copper alloyed with arsenic, expressed as the percentage of the total number of these objects in this group

For information on subdivisions see figure 3

higher than that of the other objects in this group. It is of the thick-butted or Lough Ravel type, but is narrower and has straighter sides than the majority of these axes.

One object which might be expected to have an anomalous composition in fact does not. This is the double axe, No. 152, a supposed import. A halberd, No. 133, of miscellaneous form, the only one of its type known from Ireland, could likewise be expected to have an anomalous composition, but does not. If these were not made in Ireland then they were made elsewhere from either Irish metal or a metal with a composition so similar to Irish metal as to be indistinguishable.

It is possible to subdivide this group into two on the basis of the antimony content. In 7 objects antimony is recorded as a trace or is not detected, while in the majority it is present in higher percentages. These 7 objects are, No. 67, the axe referred to above as having an anomalous composition and the miscellaneous halberd, No. 133, also mentioned. Axe No. 132 of type Lough Ravel or thick-butted type is the same axe from which analysis No. 140 was taken. This latter analysis is not included in this subgroup. Although the figures for antimony for this axe were double-checked with the sources of the analyses, no discrepancy was found. The possibility of a misprint of one of the figures cannot be ruled out. The other 4 objects are halberd No. 214 of type Cotton, axe No. 134 of anomalous form or type Lough Ravel, axe No. 205 (a miniature thin-butted axe) and axe No. 216 of hybrid form or subtype Ballybeg.

Of these 7 objects, 3 are from 'northern Ireland', 3 are from 'Ireland', and the seventh, No 132, already mentioned is from Ballybay, Co. Cork.

Similarly, on silver content two sub-groups can be formed. That with silver present as a trace or not detected again contains 7 objects. No. 103 which lies midway between the two sub-groups could belong to either. It is an axe from Cappeen, Co. Cork, possibly from the hoard of six axes found there. The other four analysed axes from Cappeen are in the sub-group with the higher silver content. If these axes are from the Cappeen hoard, it is likely that No. 103 belongs with the sub-group with the higher silver content.

Included in the sub-group with a low silver content are 4 objects, Nos. 67, 205, 133 and 214, with a low antimony content. The other three objects are 2 halberds, Nos. 210 and 211 of types Cotton and Carn respectively and an axe of type Ballyvalley, No. 131.

Five of these seven objects with low silver content have provenance no more detailed than 'Ireland'. The other two are from 'northern Ireland'.

Copper alloyed with arsenic and tin

Table III (see page 121); fig. 7; fig. 8.

There are 45 objects in this group of which 33 are axes, 10 are halberds and daggers, 1 is a socketed chisel and 1 a dagger-shaped pendant. All but two of the axes and all of the halberds can be assigned to types. Four halberds are of type Breaghwy and 2 are of miscellaneous type. Of the four daggers two are of miscellaneous

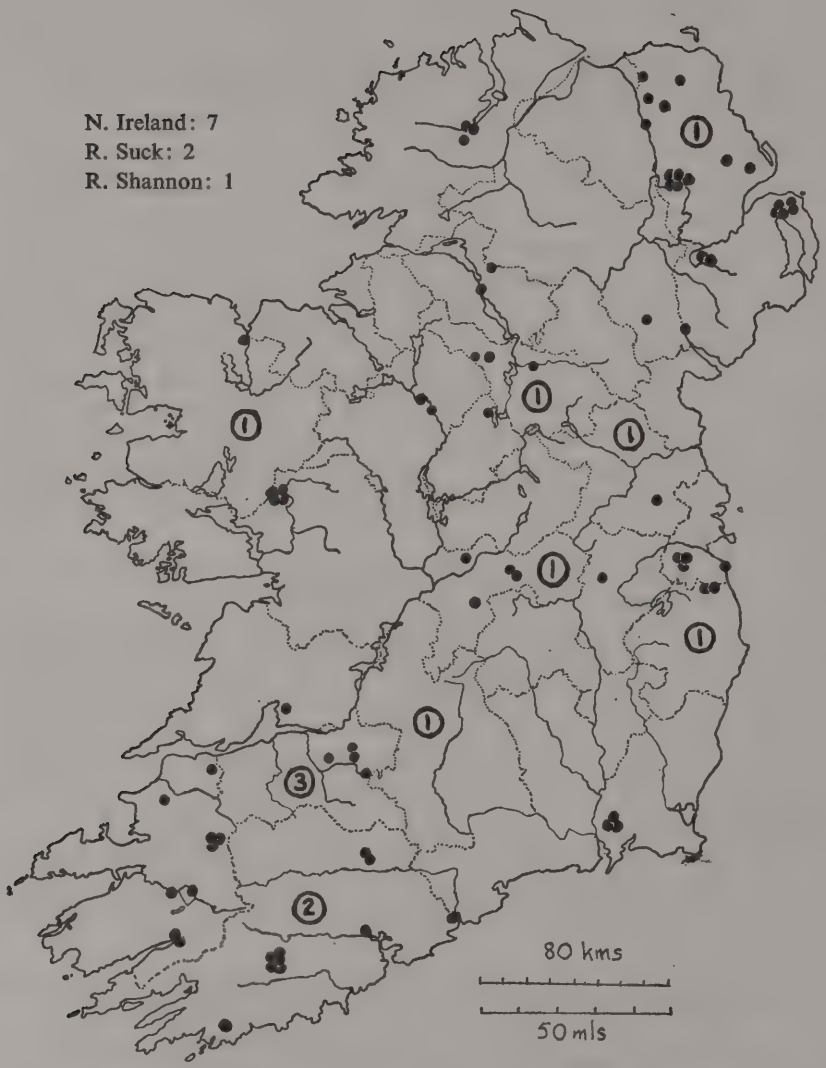


Figure 6 The distribution of objects of copper alloyed with arsenic
Figures in circles indicate the number of objects whose provenance is given as the county only

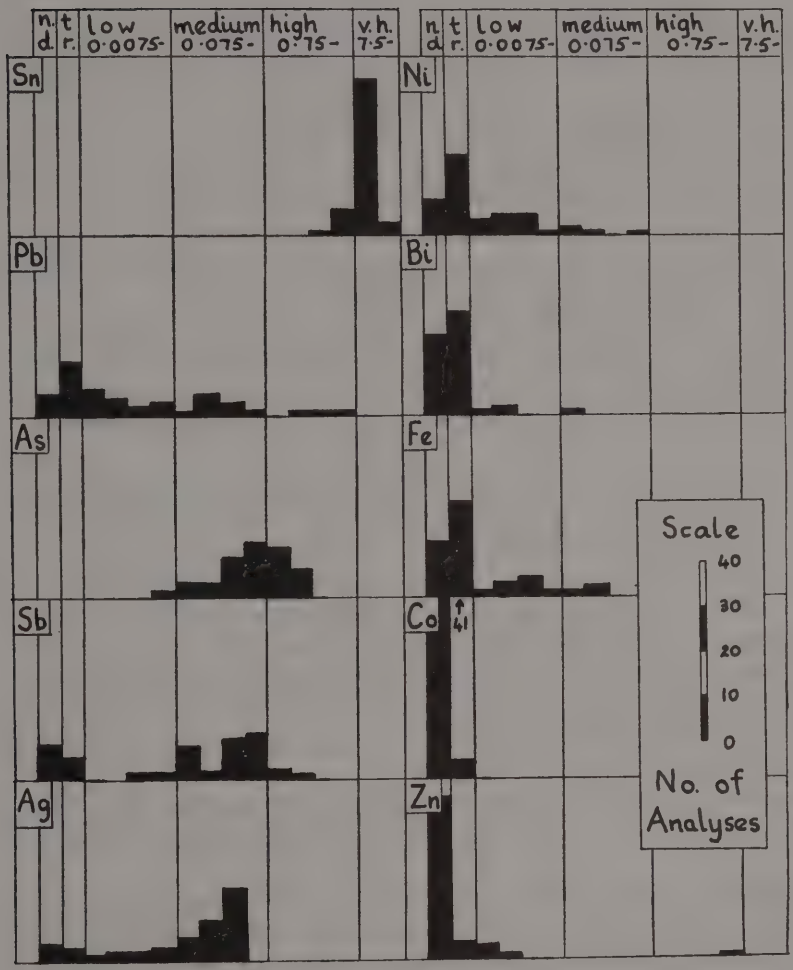


Figure 7 The composition of objects alloyed with arsenic and tin
Total number of analyses=45. *For information on subdivisions see figure 3*

type, one is unfinished and one is metal-hilted. Three axes are flanged and one is of an imported type. Four axes belong to Case's hybrid types and the remaining 24 are of his thin-butted form. According to Harbison's typology, two axes are of sub-type Ballybeg, 14 of type Killaha, 7 of type Ballyvalley and 5 of type Derryniggin.

These objects would appear to belong to Harbison's phases III, IV and V (Case's phases 2b and 3). Of the four axes of hybrid type according to Case (i.e. belonging to his phase 2a), two, of type Killaha according to Harbison, are of Case's type AB, i.e. of thin-butted shape in plan but with a thick butt.[31] However the butts of these axes from the illustrations[32] appear to have been damaged or altered. They could therefore originally have been thin-butted, and would thus not date from phase 2a.

Twenty-nine of the objects have provenance given as 'Ireland', four as 'Co. Cork' and one as 'Co. Carlow'. Eleven have a more precise provenance (fig. 8), eight coming from northern Ireland, three from southern Ireland. The overall north:south ratio is therefore 8:8, a much more even distribution.

Although the figures are not given here, axes Nos. 161 and 162 have a higher phosphorus content than the remainder in which phosphorus is not detected. Both are decorated. No. 161 is of type Derryniggin and No. 162 of type Ballyvalley. Neither is in any way of unusual type or form. No. 161 is from 'Ireland', No. 162 from Bushmills, Co. Antrim.

No. 199, a flanged axe of imported type, can be distinguished from the rest by its high bismuth and particularly its high zinc content. The lead content of this axe is higher then in most of the others. There are however two other objects with a similar high level of lead. They are No. 219, an ordinary thin-butted or type Killaha axe, and No. 201, a socketed chisel. No. 201 has the highest lead content of the three. These three objects are only slightly separated from the remainder on their lead content. Lead is considered to facilitate casting, an obvious advantage with a socketed object like the chisel. Deliberate alloying with lead does not become standard practice till the Late Bronze Age. It is quite likely that this implement dates from after the Early Bronze Age.

The composition of No. 202, the dagger-shaped pendant, differs only slightly from the remainder in its nickel content which is a little higher than that generally found.

As with the group alloyed only with arsenic, this group can be subdivided on the content of antimony and silver. The sub-group in which antimony is found as a trace or is not detected contains 13 objects. These are No. 235, the metal-hilted dagger, No. 215, a halberd of miscellaneous type (the other halberd of this type, No. 218, is alloyed only with tin), No. 206, an axe of sub-type Ballybeg, No. 176, a flanged axe, Nos. 161, 209, 227, axes of type Derryniggin, Nos. 162, 225, 226, axes of type Ballyvalley and Nos. 167, 168, 172, axes probably of type Ballyvalley. Of these

[31] Case, *op. cit.* fn. 15, 150.
[32] Harbison, *op. cit.* fn, 19, Pl. 24, no. 10 and Pl. 21, no. 12.

Figure 8 The distribution of objects of copper alloyed with tin and arsenic
Figures in circles indicate the number of objects with provenance given only as the county

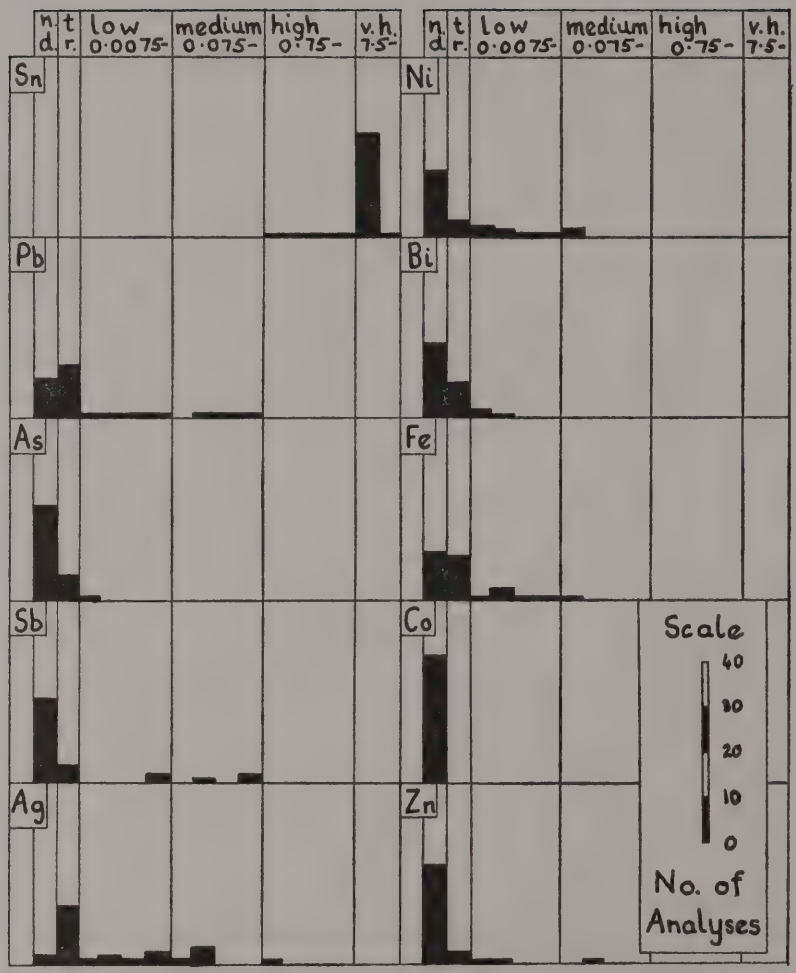


Figure 9 The composition of objects alloyed with tin
Total number of analyses = 28. *For information on subdivisions see figure 3.*

13 objects, 10 have provenance given as 'Ireland', two are from 'northern Ireland' and the metal-hilted dagger (one of two found in Ireland) is from Co. Cork.

On the silver content, the sub-group in which silver is found as a trace or is not detected contains seven objects, Of these, Nos. 206, 209, 227, are also in the sub-group with low antimony. The other four objects are—No. 207, an axe of bevelled or Killaha type, No. 234, an unfinished dagger, Nos. 212 and 213, daggers of miscellaneous type. The provenance of these seven objects is given as Ireland. No. 162, an axe of type Ballyvalley from Bushmills, Co. Antrim, could belong with this sub-group or to the sub-group with a higher silver content.

Copper alloyed with tin

Table IV (see page 126); fig. 9; fig. 10.

There are 28 objects in this group, all of which can be assigned to types. Three are halberds and daggers. Of these, one is a halberd of miscellaneous form similar to No. 215, one is a dagger of type Dunshaughlin and one a dagger of a type similar to type Dunshaughlin. The remaining 25 objects are axes. Of these, 7 are flanged. According to Harbison's typology, of the remainder, 4 are of type Derryniggin, 11 of type Ballyvalley, 1 of type Killaha, 1 is an 'ingot' and the type of one is not known. According to Case's typology all of these are of thin-butted form except for No. 170, which is a hybrid and No. 232 and No. 160 which are of thick-butted anomalous type.

These would belong to Case's phases 2b and 3 or Harbison's IV and V and possibly some of phase III since Dunshaughlin daggers date from phases III and IV.

Twenty of these objects have provenance given as 'Ireland' and one is from 'Co. Cork'. Of the remaining 7 with more precise provenance, five are from northern Ireland, one is from Co. Tipperary and one from Co. Cork. The majority of objects in this group appear to be confined to the north of Ireland. But seven is perhaps not a large enough sample to be representative and if the provenances of the 20 objects listed as from Ireland were known the picture could be altered considerably.

Twenty-eight is not a very large sample and may not therefore be truly representative. This must be borne in mind when interpreting fig. 9.

No. 224, a decorated axe of type Derryniggin and in no way of an anomalous type has a far higher zinc content than the remainder of the group. No. 136 is slightly anomalous in its silver content; this is a flanged axe. The two daggers, Nos. 181 and 182, and a decorated axe of type Ballyvalley, No. 208, have a slightly higher lead content than the majority. No. 137, a possible import, does not appear to be anomalous in its composition and may therefore have been manufactured in Ireland; it may be of Irish metal but not Irish manufacture, or of a metal very similar in composition to Irish metal and not distinguishable from it by this method.

As before, this group can be subdivided on its antimony and silver content. The sub-group in which antimony is found as a trace or is not detected contains 23 objects. These include the two daggers, Nos. 181 and 182, No. 137, the 'imported'

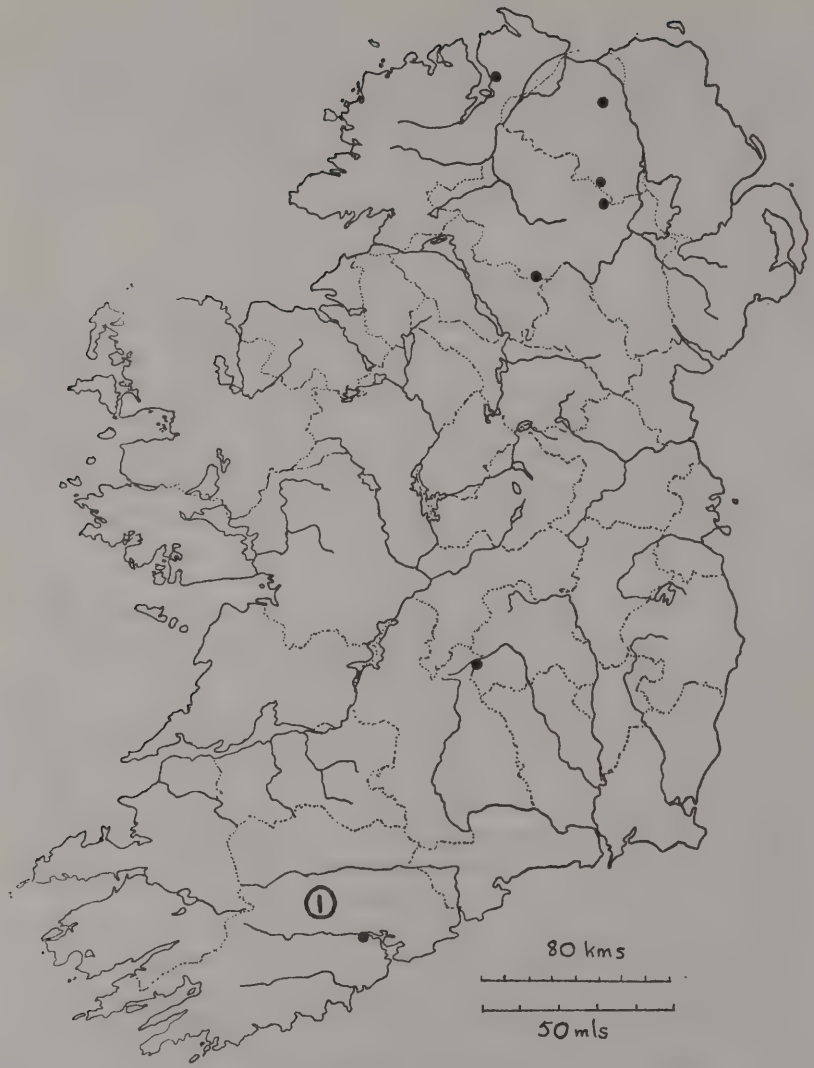


Figure 10 The distribution of objects of copper alloyed with tin

The figure in a circle indicates that there is one object in this group whose provenance is given only as Co. Cork

axe, No. 170, an axe of hybrid type, No. 232, an 'ingot', Nos. 223, 224, 228, axes of type Derryniggin, Nos. 166, 169, 200, 229, 230, axes given as of flanged type and Nos. 171, 174, 177, 180, 185, 186, 188, 189, 198, 208, axes of type Ballyvalley. Seventeen of these have provenance given as 'Ireland' and of the remaining six, five are from northern Ireland.

The sub-group in which silver is found as a trace or is not detected contains 15 objects. These are the two daggers, Nos. 181 and 182, No. 137, the 'imported' axe, Nos. 174, 177, 185, 186, 189, 198, 222, axes of type Ballyvalley, Nos. 223, 224, 228, axes of type Derryniggin, No. 232, an 'ingot', and No. 169 an axe with slight flanges. Of these, 13 have provenance given as 'Ireland', one is from Co. Donegal and one is from Co. Cork. No. 208, a type Ballyvalley axe from Co. Derry could belong with this sub-group or the sub-group with a higher silver content.

Discussion

From figs. 3, 4, 7, 9, it can be seen that apart from the tin and arsenic content, the ranges of the percentages of the elements present are consistent within all four groups of metals distinguished here. The proportions of the trace elements therefore do not alter with time during the Early Bronze Age. Alloying with arsenic and tin does not appear to alter these proportions noticeably.

The four groups can all be subdivided on the basis of their antimony and silver content. These divisions do not appear to have any typological significance, most types being represented. Their geographical distributions do however appear to have some significance. (Figs. 11 and 12).

The sub-groups with low antimony contain 46 objects altogether. Of these, 32 have provenance given as 'Ireland', one is from Co. Dublin, two are from Co. Cork, one from N. Ireland. Of the 10 with more precise provenance, one is from Cork, the remaining nine from northern Ireland. Therefore their distribution is predominantly northern (fig. 11). The three objects from Co. Cork include No. 132 mentioned previously as perhaps belonging to the sub-group with a higher antimony content, No. 235, the metal-hilted dagger and No. 200, a flanged axe of a date possibly later than the Early Bronze Age. These three objects which do not appear to fit in with the distribution of the others with a low antimony content are in themselves somewhat unusual as to type or as in the case of No. 132 may not belong in this sub-group.

The distribution of the sub-groups with higher antimony is complementary to that of the sub-group with low antimony but there are still a considerable number of objects from the north of Ireland in this group.

The sub-groups with a low silver content contain 33 objects including the two mentioned as possibly belonging to this group (Nos. 162 and 208). Of these, 25 have provenance given as 'Ireland', one is from N. Ireland, two are from Co. Cork, one is from Co. Dublin and four have a more precise provenance, all four in northern Ireland (fig. 12).

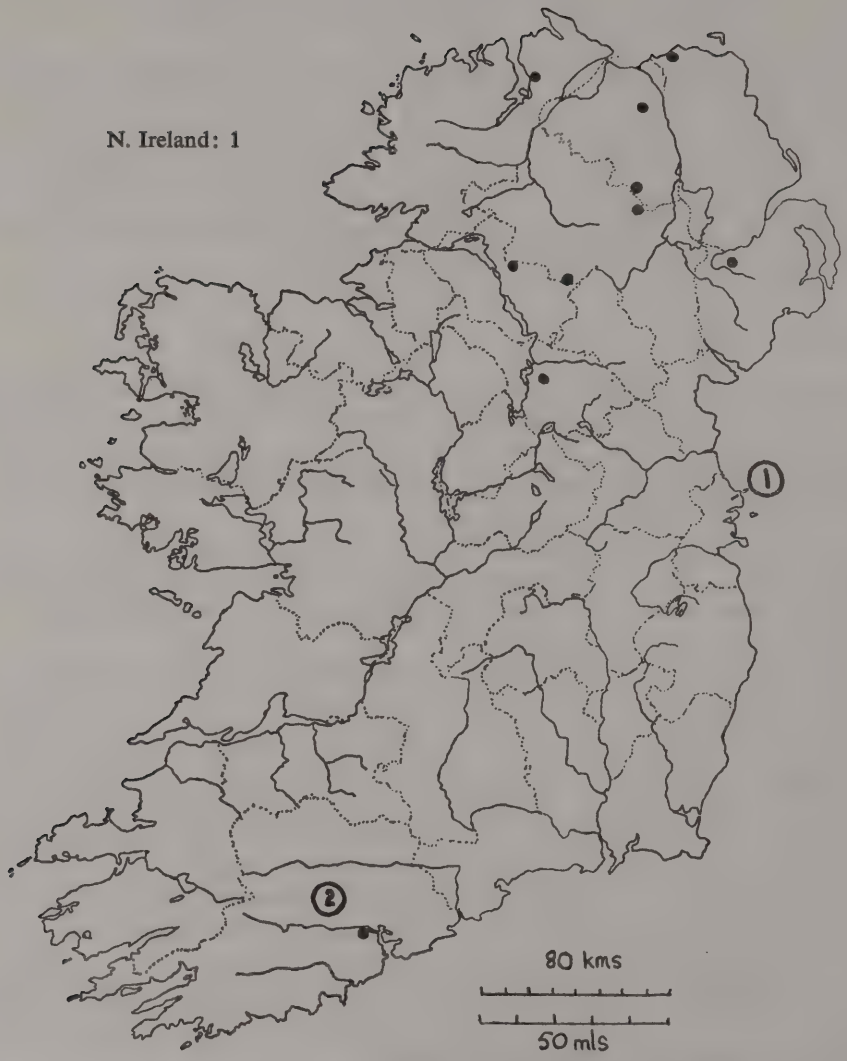


Figure 11 The distribution of objects in the sub-groups with a low antimony content
Figures in circles indicate the number of objects whose provenance is given as only the county.

There are 55 objects in these sub-groups, 24 of which occur in both the sub-groups with a low antimony content and the sub-groups with a low silver content. Therefore in nearly half these objects the low antimony appears to be connected with the low silver content.

Both the sub-groups with low antimony and the sub-groups with low silver seem to be connected with northern Ireland. It is possible that they represent the products of a metal industry based in that region producing a product distinct from all other products in its content of antimony and silver. This could be due to the use of different smelting techniques or more probably to the use of different ore sources, in which the antimony and silver content is lower than that of the other ores used. However, as has already been stated, (see p.76) the analyses of ores available are not representative particulary in respect of the ore sources in the north of Ireland. (fig. 1). It is not possible therefore to suggest any ore sources which might on smelting produce a metal of the neccessary composition.

Whether these sub-groups are the result of different smelting techniques or of the use of different ores, or both, the use of the metal of these sub-groups appears to increase with time. In the four groups of metal respectively, the sub-groups with a low antimony content account for 42½%, 4½%, 29% and 82% of each group, and the sub-groups with a low silver content account for 28½%, 4½%, 18% and 57% of each group. The percentages for the group consisting of unalloyed copper can be ignored because of the small number of objects in this group.

From fig. 13 above it can be seen that the earliest types are of unalloyed copper or copper alloyed with arsenic. Alloying with tin as well as arsenic appears according to Harbison's typology with type Killaha axes and type Breaghwy halberds, or according to Case's typology with the thin-butted axes, i.e. in Harbison's phase III or in Case's phase 2a. Alloying with tin but not arsenic appears with the introduction of type Ballyvalley axes, i.e. in Harbison's phase IV or Case's phase 2b. It is also clear that the introduction of a new type of alloy did not preclude the use of the old type, a fact which is hardly surprising.

It appears that in an early phase copper was used unalloyed or alloyed with arsenic. There is very little to suggest the use of unalloyed copper before copper was alloyed with arsenic, as there are only seven objects analysed that are of unalloyed copper. Of these, ignoring the rivet No. 62 which could be of unalloyed copper for reasons previously mentioned (see p.84) and one axe of unknown type No. 83, of the remaining five axes only one need belong to Harbison's phase II or Case's phase 2a, and this axe, No. 63, has had its butt altered in recent times. It might therefore be possible to postulate a short phase in which unalloyed copper was used before alloying with arsenic was introduced. On the other hand the types made of unalloyed copper are very similar to those of copper alloyed with arsenic and it is possible that these objects of unalloyed copper were manufactured at a time when arsenic was scarce or in a region where for some reason it was not available.

Figure 12 The distribution of objects in the sub-groups with a low silver content
Figures in circles indicate the number of objects whose provenance is given only as the county

Later alloying with tin was introduced. According to Case[33] this coincides with the arrival of the Beaker people and the beginning of his phase 2a. According to Harbison alloying with tin appears in phase III with type Killaha axes and type Breaghwy halberds. At first it appears that the old custom of alloying with arsenic was continued and that later, during Harbison's phase IV or Case's phase 2b, it was found unnecessary to use both arsenic and tin, and arsenic ceased to be used. This of course would also make the metal smith's work less dangerous.

Most halberds (types, Cotton, Carn, Clonard) are of copper alloyed with arsenic. The first daggers, those or beaker type, e.g. No. 109, are also of copper alloyed with arsenic. According to Case[34] these are some of the innovations introduced by the Beaker people at the beginning of his phase 2a along with the introduction of alloying with tin. If this is so, why were no halberds or daggers of this period alloyed with tin?

If the halberds and alloying with tin were introduced by the Beaker people, then for some reason a tin alloy was never apparently used for the manufacture of halberds. The large number of halberds of types Carn, Cotton and Clonard (48, 89, and 24 respectively) precludes the idea of a short period after the arrival of the Beaker people and before the introduction of a tin alloy.

The hoard from Hillswood, Co. Galway, contains halberds of types Carn and Cotton.[35] The hoard from Frankford, Co. Offaly contains along with a halberd of type Cotton, a dagger of type Corkey, an axe of type Lough Ravel and an axe of sub-type Ballybeg.[36] The find from Hillswood suggests that types Carn and Cotton were at least in part contemporary. The association at Frankford of a halberd of type Cotton with axes of Harbison's phases I and II suggests that this find belongs to the transitional period between the two phases. (The type Corkey dagger probably belongs to phase II.) If as Harbison suggests,[37] some type Carn halberds are slightly earlier than type Cotton halberds, then these type Carn halberds could belong in his phase I, prior to the arrival of the Beaker people, according to Case, i.e. before the introduction of alloying with tin.

The daggers of Harbison's type Knocknague, i.e. those considered to be of beaker type, belong according to Case to his 'impact' phase and were introduced by the Beaker people.

At Whitespots, Co. Down, a dagger of type Knocknague is associated with a Lough Ravel axe, and at Knocknague, Co. Galway, a similar dagger is associated with an axe of type Lough Ravel and an axe of sub-type Ballybeg.[38] The find from Knocknague suggests a date contemporary with the Frankford hoard for the Knocknague daggers. The Whitespots find could suggest an earlier beginning. These Knocknague daggers are probably therefore contemporary with halberds of

[33] Case, *op. cit.* fn. 15, 168.
[34] Case, *op. cit.* fn. 15, 168.
[35] Harbison, *op. cit.* fn. 18, 60.
[36] Harbison, *op. cit.* fn. 18, 60.
[37] Harbison, *op. cit.* fn. 20, 50.
[38] Harbison, *op. cit.* fn. 18, 60.

TYPE	PHASE	UNALLOYED COPPER	COPPER ALLOYED WITH ARSENIC	COPPER ALLOYED WITH ARSENIC AND TIN	COPPER ALLOYED WITH TIN
<u>According to Harbison:</u>					
Lough Ravel	I	2	28		
Ballybeg	II	1	2	2	
'Ingots'	I & II	2	7		1
Killaha	III		1	14	1
Ballyvalley	IV		1	7	11
Derryniggin	V			5	4
Carn	II		10		
Cotton	II		27		
Clonard	II		7		
Breaghwy	III		1	4	
Daggers			7		
Miscellaneous				3	
Dunshaughlin	III				1
<u>According to Case:</u>					
Thick-butted axes	1	1	21		
Hybrid axes	2a/2b	1	9	4	1
Thin-butted axes	2a/2b		3	24	15
Total number of objects per group		7	153	45	28

Figure 13 The number of objects of each type that are found in the four groups of metals distinguished here

types Carn and Cotton and some could possibly be earlier, i.e. perhaps contemporary with the earliest type Carn halberds.

A similar date for the introduction of halberds and daggers therefore seems likely. The Knocknague daggers are clearly associated with the Beaker people in England, e.g. at Dorchester, Winterslow, and Roundway.[39] This would suggest the arrival of the Beaker people prior to the introduction of a tin alloy, i.e. in Harbison's phase I or Case's phase 1, and that the innovations associated by Case with the Beaker people should be associated with whatever led to the introduction of alloying with tin. The possibility of a metal industry in Ireland prior to the arrival of the Beaker people cannot be excluded,[40] but the existence of such an industry cannot be conclusively proved.

It is clear that the four groups of metals mentioned above were not mutually exclusive of each other but overlap chronologically. If they form a chronological succession then on composition alone, Harbison's type Derryniggin axes could belong to either his periods III or IV or both. Harbison admits an overlap between his types Ballyvalley and Derryniggin.[41] Using finds from England which contain axes similar to type Derryniggin he claims a later date for these axes than for most of those of type Ballyvalley. However two of the three hoards containing type Derryniggin axes also contain axes of type Ballyvalley. These are, Bandon, Co. Cork, and Scrabo, Co. Down. Although it is possible that some Ballyvalley axes are earlier than those of type Derryniggin it is probable that type Derryniggin axes are contemporary with the later axes of type Ballyvalley.[42]

Apsimon[43] considers that Harbison's types Ballyvalley and Killaha are contemporary, using the mould from Ballynahinch, Co. Down, as evidence.[44] and also by disputing the affinities of the dagger in the Killaha hoard.[45]

If Apsimon is correct, Derryniggin axes could be contemporary or overlap in time with axes of both types Killaha and Ballyvalley.

I should like to thank Professor J. D. Evans and Dr. F. R. Hodson, who supervised this study, for their help and encouragement and also Mr. P. T. Craddock of the British Museum Research Laboratories for stimulating discussions on metallurgy.

[39] Case, *op. cit.* fn. 15, 156.
[40] Case, *op. cit.* fn. 15, 168.
[41] Harbison, *op. cit.* fn. 19, 79.
[42] Harbison, *op. cit.* fn. 18, 60.
[43] Apsimon, *op. cit.* fn. 29.
[44] A. E. P. Collins, 'Bronze Age Moulds in Ulster', *Ulster Journal of Archaeology* 33 (1970), 24.
[45] Harbison, *op. cit.* fn. 18, 52.

TABLES I—IV

In the tables further information is given about the analysed objects discussed in this paper.

Table I — Unalloyed Copper
Table II — Copper alloyed with arsenic
Table III — Copper alloyed with arsenic and tin
Table IV — Copper alloyed with tin

The objects are divided into axes, halberds and daggers, and miscellaneous objects and are listed within these groups in numerical order.

For further information relating to the types listed in the tables see Case 1966; Harbison 1969a, 1969b; Megaw and Hardy 1938; O'Riordain 1936. References given in Harbison's papers are not repeated in 'Other References' here.

The following abbreviations are used for works referred to in the Tables:—

Allen *et al* 1970 — I. M. Allen, D. Britton, H. H. Coghlan, *Metallurgical Reports on British and Irish Bronze Age Implements and Weapons in the Pitt Rivers Museum*, Pitt Rivers Museum, Occ. Papers on Technology 10 (Oxford, 1970).

Case 1954 — H. J. Case, 'Studies of Irish and British Early Copper Artifacts: Second series', *Man* 54 (1954), 18–27.

Case 1966 — H. J. Case, 'Were the Beaker-People the First Metallurgists in Ireland?', *Palaeohistoria XII* (1966), 141–177.

Case 1970 — H. J. Case, 'Early Bronze Age Flat Axeheads with Bevelled Sides', *Actes du VII Congrès International des Sciences Pre- et Protohistorique, Prague 1966*, Section IVB (1970).

Coghlan 1951 — H. H. Coghlan, *Notes on the Prehistoric Metallurgy of Copper and Bronze in the Old World*, Pitt Rivers Museum, Occ. Papers on Technology 4 (Oxford, 1951).

Coghlan 1953 — H. H. Coghlan, 'Studies of British and Irish Celts: First series', *Man* 53 (1953), 97–101.

Coghlan 1967 — H. H. Coghlan, 'An examination of two Bronze Age Flat Axes from Ireland', *Archaeologia Austriaca* 41 (1967), 48.

Coghlan 1968 — H. H. Coghlan, 'A Metallurgical Examination of some Prehistoric Flat and Flanged Axes, '*Archaeologia Austriaca* 44 (1968), 61–82

Coghlan and Case 1957 — H. H. Coghlan and H. J. Case, 'Early Metallurgy of Copper in Ireland and Britain', *P.P.S.* 23 (1957), 91–123.

Coghlan *et al* 1963 — H. H. Coghlan, J. R. Butler, G. Parker, *Ores and Metals*, Royal Anthropological Institute, Occ. Paper 17 (London, 1963).

Harbison 1968–69 — P. Harbison, 'Catalogue of Irish Early Bronze Age Associated Finds containing Copper or Bronze, *Proc. R. Irish Acad.* 67C, 35–91.

Harbison 1969a — P. Harbison, *The Daggers and Halberds of the Early Bronze Age in Ireland*, Prähistorische Bronzefunde VI.I. (Munich, 1969).

Harbison 1969b — P. Harbison, *The Axes of the Early Bronze Age in Ireland*, Prähistorische Bronzefunde IX.I. (Munich, 1969).

Junghans *et al* 1968 — S. Junghans, E. Sangmeister, M. Schröder, *Kupfer und Bronze in der fruhen Metallzeit Europas*, SAM II (Berlin, 1968).

Megaw 1969 — J. V. S. Megaw, 'Analyses of British and Irish Early Bronze Age Axes in the Nicholson Museum, Sydney', *P.P.S.* 35 (1969), 358–363.

Megaw and Hardy 1938 — B. R. S. Megaw and E. M. Hardy, 'British Decorated Axes and their Distribution during the Earlier part of the Bronze Age', *P.P.S.* 4 (1938), 272–307.

O'Riordain 1936 — S. P. O'Riordain, 'The Halberd in Bronze Age Europe: A Study in Prehistoric Origins, Evolution, Distribution and Chronology', *Archaeologia* 86 (1936), 195–231.

Otto and Witter 1952 — H. Otto and W. Witter, *Handbuch der ältesten vorgeschichlichen Metallurgie Mitteleuropa* (Leipzig, 1952).

Penniman and Allen 1960 — T. K. Penniman and I. M. Allen, 'A Metallurgical Study of four Irish Early Bronze Age Ribbed Halberds in the Pitt Rivers Museum, Oxford', *Man* 120 (1960), 85–98.

Richards and Blin-Stoyle 1961 — E. E. Richards and A. E. Blin-Stoyle, 'A Study of the Homogeneity in Composition of an Irish Thick-butted Axe', *Archaeometry* 4 (1961), 53.

Museums

AMO — Ashmolean Museum, Oxford
BM — British Museum
NMD — National Museum of Ireland, Dublin
NME — National Museum of Antiquities of Scotland, Edinburgh
NMS — Nicholson Museum, Sydney
PRO — Pitt-Rivers Museum, Oxford
UCD — University College, Dublin
UMB — Ulster Museum, Belfast
UMC — University Museum of Archaeology and Ethnology, Cambridge

TABLE I: UNALLOYED COPPER

Object and No.	*Type* *	*Provenance*	*Museum*	*Source of Analysis*	*Other References*	*Remarks*
Axes						
63	1. Thin butt, hybrid 2. Subtype Ballybeg	Ireland	PRO PR 1433.2318	Coghlan and Case, 1957 116, No. 77	Harbison, 1969b No. 437 Allen *et al*, 1970 Report No. 10	Hammered and annealed Sharpened Butt recently altered
65	1. Anomalous 2. Lough Ravel	Trillick, Co. Tyrone	AMO 1927:2734	*ibid.* 118, No. 81	Harbison, 1969b No. 156 Case, 1966, p. 147, fig. 4, No. 5	Single find Shows recent work
66	1. Anomalous 2. 'Ingot'	Co. Cork	PRO 1431:2321	*ibid.* 118, No. 86	Harbison, 1969b No. 452 Coghlan, 1953, p. 97 Coghlan, 1951, ch. X No. 1, Pl. X.I	
83		Ireland		Coghlan, *et al* 1963, Table II, No. H63		
151	1. Thick butt: A 2. Lough Ravel	Ireland	NME DB.56	Junghans *et al* 1968, No. 7486	Harbison, 1969b No. 286	
204	1. Anomalous 2. 'Ingot'	Co. Dublin	NMS 63.230	Megaw, 1969, 360 No. 63.230; 359, fig. 1a; 362, No. 63.230		
Halberd rivet						
62	2. Halberd—type Carn	Ireland	Newbury S.224	Coghlan and Case, 1957; 116, No. 76	Harbison, 1969a No. 185	Analysis of blade—No. 56

* In the following tables the numbers 1, 2 and 3 in this column indicate classification according to Case, Harbison and O'Riordain respectively.

TABLE II: COPPER ALLOYED WITH ARSENIC

Axes						
13	1. Thick butt: A 2. Lough Ravel	Co. Mayo	PRO Tower Armoury Coll. 56	Coghlan and Case, 1957 108, No. 15	Harbison 1969b No. 128 Allen *et al*, 1970 Report No. 4	Single find Hammered and annealed Sharpened
14	1. Thick butt: A 2. Lough Ravel	Ireland	UCD Teaching coll.	*ibid.* 108, No. 16	Harbison, 1969b No. 283	
21	1. Thick butt 2. 'Ingot'	N. Ireland	Cork Public 14	*ibid.* 108, No. 24	*ibid.* No. 474	
23	1. Hybrid, bevelled 2. Lough Ravel	Creve Bog, nr. Newry, Co. Down	UMB 200:1937	*ibid.* 110, No. 27	*ibid.* No. 60 Case, 1970	Single find, from a bog
24	1. Thick butt: A 2. Lough Ravel	Ireland	PRO PR 1434 (III)	*ibid.* 110, No. 28	Harbison, 1969b No. 320 Allen *et al*, 1970 Report No. 2	Hammered and heat treated Sharpened Modern file-marks at butt and cutting-edge
25	1. Thick butt: A 2. Lough Ravel	Ballypatrick, Co. Antrim	UMB 390:1954	*ibid.* 110, No. 29	Harbison, 1969b No. 22	Single find
27	1. Anomalous 2. 'Ingot'	Ireland	PRO III	*ibid.* 110, No. 33	*ibid.* No. 498	
28	1. Thin butt: B 2. Killaha	Ireland	PRO PR 1435.2327	*ibid.* 110, No. 34	Harbison, 1969b No. 756 Allen *et al*, 1970 Report No. 9	Cold hammered Hammered and heat treated Sharpened Sides recently ground
32	1. Thick butt: A 2. Lough Ravel	Ireland	PRO PR 1433.2316	*ibid.* 110, No. 38	Harbison, 1969b No. 318 Allen *et al*, 1970 Report No. 5	Hammered and heat treated Sharpened

TABLE II *continued*

Object and No.	*Type*	*Provenance*	*Museum*	*Source of Analysis*	*Other References*	*Remarks*
34	1. Thick butt: A 2. Lough Ravel	Lough Gur, Co. Limerick	AMO 1927:2738	*ibid.* 112, No. 40	Harbison, 1969b No. 121	Single find (1)
35	1. Thick butt: A 2. Lough Ravel	Castletown Roche, Co. Cork	AMO 747:1885	*ibid.* 112, No. 41	Harbison, 1969b No. 40 Harbison, 1968–69 45; 70	Hoard(?) of 4 axes Find circumstances unknown
36	1. Thick butt: A 2. Lough Ravel	Castletown Roche, Co. Cork	AMO 748:1885	*ibid.* 112, No. 42	Harbison, 1969b No. 41 Harbison 1968–69 45; 70	Hoard(?) of 4 axes Find circumstances unknown
37	1. Thick butt: A 2. Lough Ravel	N. Ireland	Cork Public 12	*ibid.* 112, No. 43	Harbison, 1969b No. 166	
38	1. Anomalous 2. Lough Ravel	Ireland	PRO PR 1434.II	*ibid.* 112, No. 44	Harbison, 1969b No. 319 Allen *et al*, 1970 Report No. 3	Hammered and annealed Sharpened Part cutting-edge and butt altered by recent filing
39	1. Anomalous 2. 'Ingot'	Ireland	PRO PR 1432.2324	*ibid.* 112, No. 45	Harbison, 1969b No. 494 Allen *et al*, 1970 Report No. 15	Edge hammered and heat treated Cutting-edge altered Butt and sides altered Recent grinding
40	1. Thick butt: hybrid 2. Lough Ravel	Killarney, Co. Kerry	PRO PR 1434.I	*ibid.* 112, No. 46	Harbison, 1969b No. 108 Allen *et al*, 1970 Report No. 1	Hammered hot and until cold Sharpened Recent extensive grinding of surfaces
41	1. Thick butt: A 2. Lough Ravel	Armoy, Co. Antrim	AMO 1927:2735	*ibid.* 112, No. 47	Harbison, 1969b No. 12	Single find
47	1. Thin butt: hybrid 2. 'Ingot'	Ireland	PRO PR 1433:2320	*ibid.* 114, No. 55	Harbison, 1969b No. 496 Allen *et al*, 1970 Report No. 11	Hammered and annealed Cold hammered at edge Sharpened Recently ground

[1] Nos. 163 and 164 are different analyses of this axe.

48	1. Thick butt: A 2. Lough Ravel	Co. Limerick	UMB 201:1937	*ibid.* 114, No. 56	Harbison, 1969b No. 115	Single find
49	1. Hybrid 2. Lough Ravel	Ireland	Cork Public L.188 No. 16	*ibid.* 114, No. 57	Harbison, 1969b No. 216	
50	1. Thick butt: A 2. Lough Ravel	Ireland	PRO PR.II	*ibid.* 114, No. 58	Harbison, 1969b No. 322 Allen *et al*, 1970 Report No. 6	Hammered cold Sharpened
54	1. Anomalous 2. Lough Ravel	Ireland	PRO PR.1432.2325	*ibid.* 116, No. 65	Harbison, 1969b No. 317 Allen *et al*, 1970 Report No. 12	Hammered and heat treated Cutting-edge and sides damaged
55	1. Anomalous 2. 'Ingot'	Ireland	PRO PR 1431.2317	*ibid.* 116, No. 66	Harbison, 1969b No. 493 Allen *et al*, 1970 Report No. 14	Hammered and annealed Heavy hammering of cutting-edge Sharpened Extensive recent grinding
57	1. Thick butt (?) 2. 'Ingot'	Ireland	PRO PR 1433.2319(7.70)	*ibid.* 116, No. 70	Harbison, 1969b No. 495 Allen *et al*, 1970 Report No. 13	Hammered and heat treated Final cold hammering at edge. Sharpened
64	1. Hybrid, bevelled 2. Subtype Ballybeg	Ireland	PRO PR 1439	*ibid.* 118, No. 80	Harbison, 1969b No. 439 Allen *et al*, 1970 Report No. 8	Hammered and annealed Sharpened
67	1. Thick butt: A 2. Lough Ravel	N. Ireland	PRO Flower Coll.	*ibid.* 118, No. 88	Harbison, 1969b, No. 169 Allen *et al*, 1970 Report No. 7	Cold hammered Probably sharpened
69		Cordal, Co. Kerry		Coghlan *et al*, 1963 Table II, No. 115		? from hoard of 3 axes

TABLE II *continued*

Object and No.	*Type*	*Provenance*	*Museum*	*Source of Analysis*	*Other References*	*Remarks*
70		Cordal, Co. Kerry		*ibid.* Table II, No. 116		? from hoard of 3 axes
71		Dalkey, Co. Dublin		*ibid.* Table II, No. 122		
72		Cappeen, Co. Cork		*ibid.* Table II, No. 132		? from hoard of 6 axes
73		Cappeen, Co. Cork		*ibid.* Table II, No. 133		? from hoard of 6 axes
74		Cappeen, Co. Cork		*ibid.* Table II, No. 134		? from hoard of 6 axes
75		Clontoo, Co. Kerry		*ibid.* Table II, No. 135		? from hoard of 2 axes
76		Nash (= Carrickshedoge) Co. Wexford		*ibid.* Table II, No. 139		? from hoard of 4 axes and 3 pieces of copper cake
77		Nash (= Carrickshedoge) Co. Wexford		*ibid.* Table II, No. 140		? from hoard of 4 axes and 3 pieces of copper cake
78		Dromore, Co. Down		*ibid.* Table II, No. 182		
79		Ireland		*ibid.* Table II, No. 186		
80		Hospital, Co. Limerick		*ibid.* Table II, No. 193		
81		Co. Limerick		*ibid.* Table II, No. H59		

82	Ireland	*ibid.* Table II, No. H62	
84	Ireland	*ibid.* Table II, No. H64	
85	Lough Ravel, Co. Antrim	*ibid.* Table II, No. H96	? from hoard(?) of 5 axes
86	Lough Ravel, Co. Antrim	*ibid.* Table II, No. H97	? from hoard(?) of 5 axes
87	Lough Ravel, Co. Antrim	*ibid.* Table II, No. H98	? from hoard(?) of 5 axes
88	Lough Ravel, Co. Antrim	*ibid.* Table II, No. H99	? from hoard(?) of 5 axes
89	Lough Ravel, Co. Antrim	*ibid.* Table II, No. H100	? from hoard(?) of 5 axes
90	Nr. Beaufort, Killarney, Co. Kerry	*ibid.* Table II, No. H101	
91	Liscarrol, Co. Limerick	*ibid.* Table II, No. H102	
92	Co. Cork	*ibid.* Table II, No. H103	
93	Cordal, Co. Kerry	*ibid.* Table III, No. 114	? from hoard of 3 axes
94	Tallaght, Co. Dublin	*ibid.* Table III, No. 117	? from hoard of 4 axes
95	Tallaght, Co. Dublin	*ibid.* Table III, No. 119	? from hoard of 4 axes
96	Tallaght, Co. Dublin	*ibid.* Table III, No. 121	? from hoard of 4 axes

TABLE II *continued*

Object and No.	*Type*	*Provenance*	*Museum*	*Source of Analysis*	*Other References*	*Remarks*
97		Glenmere, Co. Wicklow		*ibid.* Table III, No. 123		
98		Monastery, Co. Wicklow		*ibid.* Table III, No. 124		? from hoard(?) of 3 axes and fragments of copper cake
99		Whitespots, Co. Down		*ibid.* Table III, No. 126		? from hoard of 1 axe and 2 daggers
102		Cappeen, Co. Cork		*ibid.* Table III, No. 129		? from hoard of 6 axes
103		Cappeen, Co. Cork		*ibid.* Table III, No. 131		? from hoard of 6 axes
104		Clontoo, Co. Kerry		*ibid.* Table III, No. 136		? from hoard of 2 axes
106		Kilbannon (= Knocknague), Co. Galway		*ibid.* Table III, No. 142		? from hoard of 3 axes 1 dagger and 3 awls
107		Kilbannon (= Knocknague), Co. Galway		*ibid.* Table III, No. 143		? from hoard of 3 axes, 1 dagger and 3 awls
108		Kilbannon (= Knocknague), Co. Galway		*ibid.* Table III, No. 144		? from hoard of 3 axes, 1 dagger and 3 awls
110		Cullybally, Co. Antrim		*ibid.* Table III, No. 168		
111		Skibereen, Co. Cork		*ibid.* Table III, No. 169		

112	Dundrone, Co. Tipperary	*ibid.* Table III, No. 173	
113	Lixnaw, Co. Kerry	*ibid.* Table III, No. 177	
114	Letterkenny, Co. Donegal	*ibid.* Table III, No. 178	? from hoard(?) of 3 axes
115	Craigbilly, Co. Antrim	*ibid.* Table III, No. 185	
121	Ballycullane, Co. Limerick	*ibid.* Table III, No. CPM4	
122	N. Ireland	*ibid.* Table III, No. CPM15	
123	N. Ireland	*ibid.* Table III, No. CPM18	
124	N. Ireland	*ibid.* Table III, No. CPM19	
125	Newtownsands (? Newtownsandes, Co. Kerry)	*ibid.* Table III, No. CPM276	
128	Monastery, Co. Wicklow	*ibid.* Table IV, No. 125	? from hoard(?) of 3 axes and fragments of copper cake
129	Templeport, Co. Cavan	*ibid.* Table IV, No. 194	
130	Youghal, Co. Cork	*ibid.* Table IV, No. 196	

TABLE II *continued*

Object and No.	*Type*	*Provenance*	*Museum*	*Source of Analysis*	*Other References*	*Remarks*
131	2. Ballyvalley	Ireland	Newbury 0A228	Coghlan, 1953, 97 Table I, Pl.H	Harbison, 1969b, No. 1520 Case, 1954, 22; 26 Coghlan, 1968, 70, fig. 13	Unworked apart from hammering of cutting-edge
132	1. Thick butt: hybrid 2. Lough Ravel	Bally Bay, Co. Cork	Naturhistorisches, Vienna 17874	Otto and Witter, 1952, No. Z263	Harbison, 1969b, No. 14	Single find[3]
134	1. Anomalous 2. Lough Ravel	Ireland	Historisches, Berne 13360	Junghans *et al*, 1968 No. 2986	Harbison, 1969b No. 206	
135	1. Thin butt 2. 'Ingot'	Ireland	Historisches, Berne	*ibid.* No. 3075	*ibid.* No. 472	
139	1. Thick butt: AB 2. Lough Ravel	Ireland	Schwab, Biel 6326	*ibid.* No. 3132	*ibid.* No. 207	
140	1. Thick butt: hybrid 2. Lough Ravel	Bally Bay, Co. Cork	Naturhistorisches, Vienna 17874	*ibid.* No. 3758	*ibid.* No. 14	Single find[3]
149	1. Thick butt: A 2. Lough Ravel	Ireland	NME DB4	*ibid.* No. 7473	*ibid.* No. 284	
150	1. Thick butt: A 2. Lough Ravel	Ireland	NME DB5	*ibid.* No. 7474	*ibid.* No. 285	
152	Double axe	Ireland	NME DB69	*ibid.* No. 9284	*ibid.* No. 1987	
153	1. Thick butt: A 2. Lough Ravel	Cork, Co. Cork	PRO PR1439	Coghlan, 1953, 97, Table I	*ibid.* No. 321	
163	1. Thick butt; A 2. Lough Ravel	Lough Gur, Co. Limerick	AMO 1927:2738	Richards and Blin-Stoyle, 1961, 53	*ibid.* No. 121	Single find[4] Sample taken from tip of axe

[1] No. 140 is a different analysis of this axe.
[3] No. 132 is a different analysis of this axe.
[4] Nos. 34 and 164 are different analyses of this axe.

164	1. Thick butt: A 2. Lough Ravel	Lough Gur, Co. Limerick	AMO 1927:2738	*ibid.* 53	*ibid.* No. 121	Single find[5] Sample taken from centre of axe
203	1. Thick butt: A 2. Lough Ravel	Dunloy, Co. Antrim	NMS 63.247	Megaw, 1969, 358; 361, fig. 2a; 362, No. 63.247	*ibid.* No. 77	Single find
205	1. Thin butt: B	Ireland	NMS 62.277	Megaw, 1969, 360; No. 62.277; 361 fig. 2c; 362, No. 62.277		Miniature axe
216	1. Hybrid: thin butt 2. Subtype Ballybeg	Dromore, Co. Down	BM WG. 1526	Coghlan, 1953, 97 Table I, Pl. H	*ibid.* No. 369	Single find
Halberds						
1	2. Cotton 3. Type 5	Tullamore, Co. Offaly	NMD SA.1913:112	Coghlan and Case, 1957, 106, No. 1	Harbison, 1969a, No. 237	Single find
2	2. Clonard 3. Type 1	Ireland	UMB 134:1911	*ibid.* 106, No. 2	Harbison, 1969a, No. 285	
3	2. Carn 3. Type 5	Ireland	Cork Public 58	*ibid.* 106, No. 3	*ibid.* No. 169	
4	2. Carn 3. Type 4	N. Ireland	Cork Public 59	*ibid.* 106, No. 4	*ibid.* No. 163	
5	2. Carn 3. Type 4	Ireland	Bristol F.864	*ibid.* 106, No. 6	Harbison, 1969a No. 168 (given as Coghlan and Case analysis No. 13)	
6	2. Clonard 3. Type 2	Ireland	NMD W.269	*ibid.* 106, No. 7	Harbison, 1969a, No. 288	

[5] Nos. 34 and 163 are different analyses of this axe.

TABLE II *continued*

Object and No.	*Type*	*Provenance*	*Museum*	*Source of Analysis*	*Other References*	*Remarks*
7	2. Clonard 3. Type 2	Ireland	UMB 101:1906B	*ibid.* 106, No. 8	*ibid.* No. 284	
8	2. Clonard 3. Type 2	Ireland	NMD P.255	*ibid.* 106, No. 9	*ibid.* No. 286	
9	2. Cotton 3. Type 4	R. Suck, Cos. Galway/ Roscommon	NMD 1881:24	*ibid.* 106, No. 11	*ibid.* No. 236	Single find
10	2. Clonard 3. Type 2	Derrycassan Lake, Co. Cavan	NMD R.1576	*ibid.* 106, No. 12	*ibid.* No. 281	Single find
11	2. Carn 3. Type 4	Ireland	Bristol E.1774	*ibid.* 106, No. 13	*ibid.* No. 167 (given as Coghlan and Case analysis No. 6)	
12	2. Cotton 3. Type 5	Lough Gur, Co. Limerick	NMD 1891:13	*ibid.* 108, No. 14	*ibid.* No. 227	Single find
15	2. Cotton 3. Type 4	Cotton Moss, Cotton, Co. Down	NMD 1929: 1499	*ibid.* 108, No. 17	*ibid.* No. 206 Harbison, 1968–69, 47; 73	Hoard of 3 halberds
16	2. Cotton 3. Type 4	R. Shannon	Blackmore, Salisbury 307, Brackstone Coll.	*ibid.* 108, No. 18	Harbison, 1969a, No. 233	Single find
17	2. Cotton 3. Type 5	Clonloghan, Co. Clare	NMD R.2553	*ibid.* 108, No. 19	*ibid.* No. 199	Single find
18	2. Cotton 3. Type 5	Letterkenny, Co. Donegal	AMO 1927:2831	*ibid.* 108, No. 20	*ibid.* No. 226 Harbison, 1968–69, 54; 86	Hoard(?), ? associated with tanged chisel

19	2. Cotton 3. Type 5	Ireland	UCD Teaching coll.	*ibid.* 108, No. 21	Harbison, 1969a, No. 264	
20	2. Cotton 3. Type 5	Ballyhaise, Co. Cavan	Blackmore, Salisbury 362 Brackstone Coll.	*ibid.* 108, No. 22	*ibid.* No. 194	Single find
22	2. Clonard 3. Type 2	Tullyvallan, Co. Armagh	NMD SA.1927:44	*ibid.* 108, No. 26	*ibid.* No. 282	Single find
26	2. Cotton 3. Type 5	Ireland	AMO 1927:2830	*ibid.* 110, No. 30	*ibid.* No. 276	
29	2. Clonard 3. Type 1	Ireland	UMB 101:1906A	*ibid.* 110, No. 35	*ibid.* No. 283	
30	2. Cotton 3. Type 5	R. Suck, Cos. Galway/ Roscommon	NMD 1881:23	*ibid.* 110, No. 36	*ibid.* No. 235	Single find
31	2. Cotton 3. Type 5	Co. Cavan	NMD W.234	*ibid.* 110, No. 37	*ibid.* No. 198	Single find
33	2. Cotton 3. Type 4	Co. Offaly	NMD 1874:32	*ibid.* 110, No. 39	*ibid.* No. 229	Single find
42	2. Carn 3. Type 4	Tullamore, Co. Offaly	UMB 107:1926	*ibid.* 112, No. 50	*ibid.* No. 161	Single find
43	2. Carn 3. Type 3	Ballyboley, Co. Antrim	NMD 1903:235	*ibid.* 112, No. 51	*ibid.* No. 144	Single find
44	2. Carn 3. Type 3	Ireland	PRO PR. 1487	*ibid.* 112, No. 52	*ibid.* No. 186 Allen *et al*, 1970 Report No. 43	Edge, heavy cold hammering. Sharpened. Hafting plate damaged.
45	2. Cotton 3. Type 5	Keeloge Ford, R. Shannon, Co. Leitrim	NMD W.263	*ibid.* 114, No. 53	Harbison, 1969a, No. 223	Single find

TABLE II *continued*

Object and No.	*Type*	*Provenance*	*Museum*	*Source of Analysis*	*Other References*	*Remarks*
46	2. Cotton 3. Type 4	Cotton Moss, Cotton, Co. Down	NMD 1929:1500	*ibid.* 114, No. 54	*ibid.* No. 207 Harbison, 1968–69, 47; 73	Hoard of 3 halberds
51	2. Cotton 3. Type 5	Frankford, Co. Offaly	UMB 480:1937	*ibid.* 114, No. 59	Harbison, 1969a, No. 214 Harbison, 1968–69, 49; 76	Hoard of 5 axes, dagger and halberd. Analysis of rivet: No. 58
52	2. Cotton 3. Type 5	Ireland	UMB 4025(9–80)	*ibid.* 114, No. 60	Harbison, 1969a, No. 240	
53	2. Cotton 3. Type 5	Portara Ford, Lough Erne, Co. Fermanagh	UMB 186:1913	*ibid.* 114, No. 61	*ibid.* No. 230	Single find
56	2. Carn	Ireland	Newbury S.224	*ibid.* 116, No. 67	*ibid.* No. 185	Analysis of rivet: No. 62
Halberd rivet						
58				*ibid.* 116, No. 71		See No. 51
Halberds						
59	2. Cotton 3. Type 5	Ballina, Co. Mayo	UMC 25.286	*ibid.* 116, No. 72	*ibid.* No. 243	
60	2. Cotton 3. Type 4	Co. Meath	NMD W.238	*ibid.* 116, No. 73	*ibid.* No. 228	Single find
61	2. Carn 3. Type 4	Ballybog(e)y Bog, Co. Antrim	AMO 1927:2848	*ibid.* 116, No. 75	*ibid.* No. 143	Single find
68	2. Similar to type Breaghwy 3. Type 3	R. Bann, nr. Kilrea, Co. Derry	UMB 1:1935	*ibid.* 120, No. 94	*ibid.* No. 307	Single find

Halberd/dagger						
100		Whitespots, Co. Down		Coghlan *et al*, 1963 Table III, No. 127		? from hoard of 1 axe and 2 daggers
Daggers						
101		Whitespots, Co. Down		*ibid.* Table III, No. 128		? from hoard of 1 axe and 2 daggers
109		Kilbannon (= Knocknague), Co. Galway		*ibid.* Table III, No. 145		? from hoard of 3 axes, 1 dagger and 3 awls
116		R. Shannon, Jamestown, Co. Leitrim		*ibid.* Table III, No. 216		
117		Kilnagarnah, Co. Offaly		*ibid.* Table III, No. 217		
118		Ireland		*ibid.* Table III, No. 218		
119		Listack, Co. Donegal		*ibid.* Table III, No. 220		
120		Dumshaughlin, Co. Meath		*ibid.* Table III, No. 221		
Halberds						
126		Allen, Co. Kildare		*ibid.* Table IV, No. 85 (1959)		
127		Croft, Co. Longford		*ibid.* Table IV, No. 86 (1959)		
133	2. Miscellaneous	Ireland	BM No number	Otto and Witter, 1952, No. Z.324	Harbison, 1969a, No. 312	

TABLE II *continued*

Object avd No.	*Type*	*Provenance*	*Museum*	*Source of Analysis*	*Other References*	*Remarks*
138	2. Cotton 3. Type 5	Ireland	Schwab, Biel 6323	Junghans *et al*, 1968, No. 3131	*ibid.* No. 242	
141	2. Cotton 3. Type 5	Ireland	NME DK.2	*ibid.* No. 7463	*ibid.* No. 266	Analysis of rivet: No. 142
Halberd rivet						
142				*ibid.* No. 7464		See No. 141
Halberd						
143	2. Cotton 3. Type 3	Ireland	NME DK.9	*ibid.* No. 7466	*ibid.* No. 267	Analysis of rivet: No. 144
Halberd rivet						
144				*ibid.* No. 7467		See No. 143
Halberd						
145	2. Cotton 3. Type 5	Ireland	NME DK.25	*ibid.* No. 7469	*ibid.* No. 268	Analysis of rivet: No. 146
Halberd rivet						
146				*ibid.* No. 7470		See No. 145
Halberds						
147	2. Breaghwy 3. Type 4	Ireland	NME DK.26	*ibid.* No. 7471	*ibid.* No. 306	
148	2. Cotton 3. Type 5	Ireland	NME DK.27	*ibid.* No. 7472	*ibid.* No. 269	

Halberd blank						
210	2. Cotton 3. Type 4	Ireland	PRO Pitt Rivers Coll.	Penniman and Allen, 1960, 88, No. 1; 89, fig. 2	*ibid.* No. 189 Allen *et al*, 1970 Report No. 42	Hammered and annealed Hammering light
Halberds						
211	2. Carn 3. Type 4	Ireland	PRO PR.1488	*ibid.* 90, No. 3; 92, No. 3a, fig. 4	Harbison, 1969a No. 187 Allen *et al*, 1970 Report No. 41	Heat treated. Edge-cold hammered. Rivet hammered with round die from piece cast rod
214	2. Cotton 3. Type 5	Bellanamallard, Co. Fermanagh	BM 64.5–3.2	Case, 1954, 18 Table I, No. 20	Harbison, 1969a No. 196	Single find
Smelted copper/copper cake						
105		Nash (= Carrickshedoge) Co. Wexford,		Coghlan *et al*, 1963 Table III, No. 141		? from hoard of 4 axes and 3 pieces of copper cake

TABLE III: COPPER ALLOYED WITH ARSENIC AND TIN

Axes, decorated						
159	1. Thin butt: B 2. Ballyvalley Megaw and Hardy, Type 1	Co. Carlow	Newbury OA.56	Coghlan and Case, 1957, 116, No. 68	Harbison, 1969b, No. 857 Coghlan, 1968, 64	Hammered and annealed Cutting-edge cold hammered
161	1. Thin butt 2. Derryniggin Megaw and Hardy, Type 3	Ireland	PRO PR.1441	*ibid.* 118, No. 84	Harbison, 1969b, No. 1855 Allen *et al*, 1970 Report No. 28	Hammered and annealed Cold hammered Sharpened. Some recent abrasion
162	1. Thin butt: B 2. Ballyvalley Megaw and Hardy, Type 1	Bushmills, Co. Antrim	AMO 1927:2755	*ibid.* 118, No. 85	Harbison, 1969b, No. 854	Single find

TABLE III *continued*

Object and No.	*Type*	*Provenance*	*Museum*	*Source of Analysis*	*Other References*	*Remarks*
167	2. ? Ballyvalley	Ireland	Newbury OA.320	Coghlan, 1968, 68		Hammered and annealed Cutting-edge cold hammered. Sharpened
Axes						
168	2. ? Ballyvalley	Ireland	Newbury OA.330	*ibid.* 71		Hammered and annealed Cutting-edge cold hammered
172	2. ? Ballyvalley	Ireland	Historisches, Berne, 13358	Junghans *et al*, 1968 No. 2985		
173	1. Thin butt: B 2. Killaha	Ireland	Schwab, Biel Irland 6324	*ibid.* 3130	*ibid.* No. 669	
175	1. Thick butt: hybrid: AB 2. Killaha	Youghal House, Co. Tipperary	Naturhistorisches, Vienna, 17875	*ibid.* 3662	*ibid.* No. 632 (given as Co. Cork)	
176	Flanged	Ireland	Toulouse 30107	*ibid.* 7028		
178	Flat	Ireland	Lausanne	*ibid.* 7259		
179	Flat	Ireland	Lausanne	*ibid.* 7260		
184	1. Thin butt: B 2. Killaha	Ireland	NME DB.12	*ibid.* 7476	*ibid.* No. 726	
187	1. Thin butt: B 2. Killaha	Ireland	NME DB.19	*ibid.* 7479	*ibid.* No. 727	
190	1. Thin butt: B 2. Killaha	Ireland	NME DB.27	*ibid.* 7482	*ibid.* No. 728	

191	1. Thin butt: B 2. Killaha	Ireland	NME DB.28	*ibid.* 7483	*ibid.* No. 729	
192	1. Thin butt: B 2. Killaha	Ireland	NME DB.35	*ibid.* 7484	*ibid.* No. 730	
193	1. Thin butt: B 2. Killaha	Ireland	NME DB.39	*ibid.* 7485	*ibid.* No. 731	
194	1. Thin butt: B 2. Killaha	Streamstown, Co. Sligo/ Co. Westmeath	NME DB.67	*ibid.* 7487	*ibid.* No. 620	Single find from a bog
195	1. Thin butt 2. Killaha	Drumquin, Drumscra Townland, Co. Tyrone	Kelvingrove, Glasgow A.5738	*ibid.* No. 9306	*ibid.* No. 512	Single find
196	1. Thick butt: AB 2. Killaha	Loch Beg, between Bellaghy and Toome, Co. Derry	Kelvingrove, Glasgow 98–228	*ibid.* No. 9307	*ibid.* No. 595	Single find
197	1. Thick butt: AB 2. Killaha	Cork, Co. Cork	Vor- und Frügeschichte, Berlin V.d.10	*ibid.* No. 9774	*ibid.* No. 549	
199	Imported Flanged	Ballycastle, Co. Antrim	Vor- und Frügeschichte, Berlin V.d.38	*ibid.* No. 9777	*ibid.* No. 1980	Single find
206	1. Thin butt: hybrid 2. Ballybeg	Ireland	NMS 63.229	Megaw, 1969, 360, No. 63.229; 361, fig. 2b; 362; No. 63.229		
207	1. Bevelled 2. Killaha	Ireland	NMS 63.228	*ibid.* 360, No. 63.228; 359, fig. 1b; 362 No. 63.228		Recent damage to butt

TABLE III *continued*

Object and No.	*Type*	*Provenance*	*Museum*	*Source of Analysis*	*Other References*	*Remarks*
209	Flanged 2. Derryniggin Megaw and Hardy, Type 3b	Ireland	NMS R472	*ibid.* 362, R472; 359 fig. 1d		
219	1. Thin butt: B 2. Killaha	Mallow, Co. Cork	PRO 1435.2327	Allen *et al*, 1970, Report No. 16	*ibid.* No. 601	Single find. Hammered and annealed. Sharpened Traces recent abrasion
220	1. Thin butt: hybrid 2. Subtype Ballybeg	Ireland	PRO PR.1439	*ibid.* Report No. 17	*ibid.* No. 438	Hammered and annealed Cutting-edge cold hammered. Sharpened. Butt damaged.
221	1. Thin butt 2. Ballyvalley	Co. Cork	PRO PR.1438	*ibid.* Report No. 22	*ibid.* No. 1276	Hammered and annealed. Sharpened. Butt slightly damaged.
225	1. Thin butt: B 2. Ballyvalley	Ireland	PRO PR.1441(I)	*ibid.* Report No. 26	*ibid.* No. 1526	Hammered and annealed. Cold hammered. Sharpened
226	1. Thin butt 2. Ballyvalley	Ireland	PRO PR.1441	*ibid.* Report No. 27	*ibid.* No. 1527	Hammered and annealed. Sharpened. Butt slightly damaged. Recent grinding sides
227	1. Thin butt 2. Derryniggin	Ireland	PRO PR.1441(2)	*ibid.* Report No. 29	*ibid.* No. 1967	Hammered and annealed. cold hammered. Sharpened. Butt slightly damaged.
231	1. Thin butt 2. Derryniggin	Ireland	PRO PR.1439(1)	*ibid.* Report No. 34	*ibid.* No. 1979	Hammered and annealed. Sharpened. Extensive recent abrasion

233	1. Thin butt 2. Derryniggin	Co. Cork	PRO PR.1444	*ibid.* Report No. 36	*ibid.* No. 1879	Hammered and annealed. Cold hammered. Sharpened.
Halberds						
155	2. Breaghwy	Limavady District, Co. Derry	UMB 745:1954	Coghlan and Case, 1957, 106, No. 10	Harbison, 1969a, No. 302	Single find
156	2. Breaghwy 3. Type 4	Co. Cork	Cork Public L.188.57	*ibid.* 110, No. 31	*ibid.* No. 299	Single find
157	2. Breaghwy 3. Type 6	Breaghwy, Co. Mayo	NMD 1937:2802	*ibid.* 114, No. 63	*ibid.* No. 297	Single find
158	2. Miscellaneous 3. Type 6	Ireland	NMD 1877:57	*ibid.* 114, No. 64	*ibid.* No. 311	
Daggers						
212	2. Miscellaneous with triangular decoration 3. Halberd, Type 5	Ireland	PRO PR.1488	Penniman and Allen 1960, 93, No. 4 (given at halberd)	*ibid.* No. 92 Allen *et al*, 1970 Report No. 39	Cold hammered. Localised annealing at edge. Sharpened
213	2. Miscellaneous	Ireland	PRO PR.1488	*ibid.* 93, No. 5	Harbison, 1969a, No. 93 Allen *et al*, 1970 Report No. 37	Hammered and annealed. Edge cold hammered. Sharpened
Halberds						
215	2. Miscellaneous	Nr. Cavan, Co. Cavan	AMO 1927:2832	Coghlan and Case, 1957, 118, No. 89	Harbison, 1969a, No. 309	Single find
217	2. Breaghwy 3. Type 5	Moylough, Achonry, Co. Sligo	NMD 1928:392.394	*ibid.* 118, No. 82	*ibid.* No. 303	Single find from cremation burial in cist with decorated capstone. Halberd burnt

TABLE III *continued*

Object and No.	*Type*	*Provenance*	*Museum*	*Source of Analysis*	*Other References*	*Remarks*
Daggers						
234	Unfinished	Ireland	PRO PR	Allen *et al*, 1970 Report No. 38		Hammered and annealed. Sharpened
235	Bronze hilted	Co. Cork	PRO PR.1487	*ibid.* Report No. 40	*ibid.* No. 79	Hammered and annealed. Cold hammered. Sharpened
Socketed chisel						
201		Ireland	Vor- und Frühgeschichte, Berlin V.d.11	Junghans *et al*, 1968, No. 9779		
Dagger-shaped pendant						
202		Ireland	Vor- und Frühgeschichte, Berlin V.d.42	*ibid.* No. 9780		

TABLE IV: COPPER ALLOYED WITH TIN

Axes						
136	Flanged	Ireland	Historisches, Berne	Junghans *et al*, 1968, No. 3076		
137	Flanged 2. ? imported	Ireland	Historisches, Berne	*ibid.* No. 3077		
160	1. Unfinished 2. Derryniggin	Ireland	PRO PR	Coghlan and Case, 1957, 116, No. 78	Harbison, 1969b, No. 1969 Allen *et al*, 1970, Report No. 33	Heavy hammering unlikely. Heated to high temperature. Considerable recent abrasion

166	Flanged	Ireland	Newbury OA.321	Coghlan, 1968, 67		Hammered and annealed. Left in annealed state. One side blade broken off
169	Slight flanges 1. Thin butt	Ireland	Newbury S.225	Coghlan, 1967 48		Left in fully annealed state. Cutting-edge cold hammered
170	Decorated 1. Thick butt: AB	Ireland	Newbury S.226	*ibid.* 57		Considerable hammering and annealing. Some hot working. Left in fully annealed state
171	1. Thin butt: B 2. Ballyvalley	Nr. Fivemiletown, Co. Tyrone	BM 43, 12–26, 2	Otto and Witter, 1952, No. Z.116	Harbison, 1969b, No. 926 Harbison, 1968–69, 48; 76	From hoard(?) of 2 axes
174	1. Thin butt: B 2. Ballyvalley	Ireland	Schwab, Biel Irland 6325	Junghans *et al*, 1968 No. 3133	Harbison, 1969b, No. 1419	
177	1. Thin butt: B 2. Ballyvalley	Ireland	Geneva 1934	*ibid.* No. 7088	*ibid.* No. 1638	
180	1. Thin butt: B 2. Ballyvalley	Ireland	Lausanne	*ibid.* No. 7261	*ibid.* No. 1499	
183	1. Thin butt: B 2. Killaha	Ireland	NME DB.10	*ibid.* No. 7475	*ibid.* No. 725	
185	1. Thin butt: B 2. Ballyvalley	Ireland	NME DB.15	*ibid.* No. 7477	*ibid.* No. 1487	
186	1. Thin butt: B 2. Ballyvalley	Ireland	NME DB.16	*ibid.* No. 7478	*ibid.* No. 1488	
188	1. Thin butt: B 2. Ballyvalley	Ireland	NME DB.22	*ibid.* No. 7480	*ibid.* No. 1489	

TABLE IV *continued*

Object and No.	*Type*	*Provenance*	*Museum*	*Source of Analysis*	*Other References*	*Remarks*
Axes, decorated						
189	1. Thin butt: B 2. Ballyvalley	Ireland	NME DB.23	No. *ibid.* 7481	*ibid.* No. 1184	
198	1. Thin butt: B 2. Ballyvalley	Buncrana, Co. Donegal	Vor- und Frühgeschichte, Berlin V.d.35	*ibid.* No. 9776	*ibid.* No. 853	Single find
Axes						
200	Flanged	Cork, Co. Cork	Vor- und Frühgeschichte, Berlin II.9496	*ibid.* No. 9778		
Axes, decorated						
208	1. Thin butt: bevelled 2. Ballyvalley Megaw and Hardy, Type Ia	Cregard Bog, Nr. Garvagh, Co. Derry	NMS 67.162	Megaw, 1969, 360 No. 67. 162; 359 fig. 1c; 362 No. 67.162	*ibid.* No. 933	Single find
Axes						
222	1. Thin butt 2. Ballyvalley	Co. Cork	PRO PR.1438	Allen *et al*, 1970, Report No. 23	*ibid.* No. 1275	Heavily hammered and annealed to high temperature. Sharpened
Axes, decorated						
223	1. Thin butt 2. Derryniggin	Ireland	PRO PR.307	*ibid.* Report No. 24	*ibid.* No. 1853	Hammered and annealed. Sharpened. Butt damaged
224	1. Thin butt 2. Derryniggin	Ireland	PRO PR.307.2877	*ibid.* Report No. 25	*ibid.* No. 1851	Hammered and annealed. Some cold hammering of sides and cutting-edge. Sharpened

228	2. Derryniggin	Ireland	PRO PR.307(1)	*ibid.* Report No. 30	*ibid.* No. 1852	Hammered and annealed. Cold hammered. Sharpened. Damage to butt and cutting-edge
229	Flanged	Cookstown, Co. Tyrone	PRO PR.1444	*ibid.* Report No. 31		Hammered and annealed. Final cold hammering. Sharpened
Axes						
230	Flanged	Slieve Gallion, Co. Derry	PRO PR.1444	*ibid.* Report No. 32		Hammered and annealed. Left annealed apart from cutting-edge—cold hammered. Sharpened. Butt recently ground
232	1. Thick butt 2. 'Ingot'	Ireland	PRO PR.1439	*ibid.* Report No. 35	*ibid.* No. 497	Cold hammered. Sharpened. Sides damaged. Some recent abrasion of surfaces
Dagger, decorated						
181	2. Similar to type Dunshaughlin	Ireland	NME DK.4	Junghans *et al*, 1968, No. 7465 (given as halberd)	Harbison, 1969a, No. 52 (given as dagger)	
Dagger						
182	2. Dunshaughlin	Ireland	NME DK.10	*ibid.* No. 7468 (given as halberd)	*ibid.* No. 49 (given as dagger)	
Halberd						
218	2. Miscellaneous	Rockforest, Co. Tipperary	NMD W.295	Coghlan and Case, 1957, 118, No. 87	*ibid.* No. 310	Single find

The Deterioration of Inorganic Materials under the Sea

by Lucy E. Weier

THE MARINE ENVIRONMENT

A discussion of the marine environment from the point of view of the marine archaeologist need not be a general summary of oceanography. Rather, it should be a more specific description of the seabed environment, for it is here that the ancient wrecks and harbours lie. One is therefore interested in the physical and chemical aspects of not only the seawater but, more important, of the bottom sediments. Also for our purposes, descriptions will deal mainly with depths less than 100 metres, as depths below this are not practical working depths for underwater archaeological sites.

PHYSICAL ASPECTS

The physical aspects of light, temperature, and water movement determine what kind of marine life will inhabit the sea. The penetration of *light* is perhaps the most important single factor as it governs the activities of the photosynthetic plankton which sustain life in the sea. The region through which light penetrates is called the euphotic zone and it is in this zone that the numbers of phytoplankton and zooplankton affect such things as the numbers of organisms, the oxygen concentration, and the pH. This often occurs in seasonal and, in some cases, diurnal cycles.

The penetration of light is also the main controlling factor in the *temperature* of the sea, its intensity and its incidence causing diurnal and seasonal changes. According to Zobell,[1] surface water temperatures usually fluctuate less than 1°C throughout the day and such diurnal changes are barely perceptible below a depth of 10 metres, but these variations are not likely to be of biological importance. Annual changes may affect the water temperatures to a depth of 10 to 200 metres depending on light penetration and water movement. Below this depth the temperatures are fairly constant except, again, in the case of water movement. The temperature of sea water usually decreases with depth except in shallow turbulent seas or during winter at high latitudes when the surface waters can be cooler. Temperature affects the kind of marine organisms and the length of their breeding season,

[1] Claude E. Zobell, *Marine Microbiology*, Waltham, Mass. (1946), 13.

life being far less seasonal in the tropics than in temperate climes. This factor will become important during discussion of microbiological and electro-chemical changes within the sediments.

It has been mentioned that *water movements* can cause changes in temperature and one should remember that this, too, can be a seasonal affair, directional changes in currents occurring at different times of the year. Vertical mixing or upwelling can also effect the temperature as well as bring nutrients to the euphotic zone which allows for greater biological activity.[2]

The Composition of Sea Water[3]

TABLE I

Concentration of elements, exclusive of gases, in sea water having a salinity of 34.325‰ (from data recorded by SVERDRUP *et al.*, 1942)

Element	*GM./KG. or ‰*	*Per cent of Total Solids*	*Element (Cont.)*	*GM./KG. or ‰*
Chlorine	18.980	55.29	Iron*	0.00,02
Sodium	10.561	30.77	Manganese*	0.000,01
Oxygen	1.733	5.05	Copper	0.000,01
Magnesium	1.272	3.71	Zinc	0.000,005
Sulfur	0.884	2.57	Lead	0.000,004
Calcium	0.400	1.16	Selenium	0.000,004
Potassium	0.380	1.11	Cesium	0.000,002
Bromine	0.005	0.189	Uranium	0.000,001,5
Carbon	0.028	0.081	Molybdenum	0.000,000,5
Strontium	0.013	0.038	Thorium	$<$0.000,000,5
Boron	0.004,6	0.013	Cerium	0.000,000,4
Silicon*	0.004,0	0.012	Silver	0.000,000,3
Fluorine	0.001,4	0.004	Vanadium	0.000,000,3
Nitrogen*	0.000,7	0.002	Lanthanum	0.000,000,3
Aluminium	0.000,5	—	Yttrium	0.000,000,3
Rubidium	0.000,2	—	Nickel	0.000,000,1
Lithium	0.000,1	—	Scandium	0.000,000,04
Phosphorus*	0.000,1	—	Mercury	0.000,000,03
Barium	0.000,05	—	Gold	0.000,000,006
Iodine	0.000,05	—	Radium*	3×10^{-13}
Arsenic*	0.000,02	—		

* The quantity of the elements marked with an asterisk is highly variable in sea water primarily due to biological activity. The concentration given is the maximum ordinarily found.

Sea water is a physiologically balanced salt solution containing more than half the known elements. It is a dilute solution of several salts with some dissolved gases and traces of many organic compounds. Except for a few constituents which are produced or consumed by biological activity, the composition of sea water is relatively constant.[4] The concentrations of the principal inorganic solutes in sea water having a salinity of 34.325 *per mille* are given in the table above.

[2] *Ibid* 14–15. [3] *Ibid* 17. [4] *Ibid* 17.

The chlorine and bromine occur almost exclusively as chloride and bromide anions. Similarly, sodium, magnesium, calcium, potassium, and strontium occur as cations. The oxygen reported in Table I (above) occurs mostly in sulphate ions, with smaller quantities in bicarbonate, borate, phosphate, nitrite, and nitrate ions and to a lesser extent in organic compounds. The ratios of the three principal anions of sea water, i.e. carbonates, sulphates, and chlorides, in sea water are the reverse of the ratios of these anions in river water:

	% Carbonate	*% Sulfate*	*% Chloride*
River water	80	13	7
Sea water	<1	11	88

Similarly the ratios of cations, particularly sodium and calcium, are different in sea water and in river water:

	% Calcium	*% Sodium*	*% Magnesium*	*% Potassium*
River water	57.7	26.8	9.5	6.0
Sea water	3.2	83.7	10.1	3.0[5]

Sea water with a salinity of 34.325 *per mille* is considered 'standard'. The *salinity* is defined as 'the total amount of solid material, in grams, contained in one kilogram of sea water when all the carbonates have been converted to oxide, the bromide and iodine replaced by chlorine, and all organic matter completely oxidized'.[6] Thus the salinity, roughly speaking, is a measure of the total salt content of sea water. This should not be confused with chlorinity which is a measure of the total amount of chlorine, bromide, and iodine in grams per kilogram of sea water.

The salinity structure of the seas in its broadest aspects resembles the temperature structure. Both show seasonal and diurnal fluctuations near the surface; both are modified by currents and mixing; both are highly variable at the surface but tend to become constant with increasing depth.[7] When a body of water is land-bound the salinity tends to be more. Thus parts of the northern Pacific,[8] Indian Ocean, Mediterranean Sea, Dead Sea, etc., will be more saline. Compare, for example, salinity readings from the Mediterranean and Dead Sea with Table I:

	Sea water analysis (g/kg)						
Component	*Na*	*K*	*Ca*	*Mg*	*Cl*	*SO^4*	*Br*
Mediterranean	10.8	0.39	0.4	1.3	19.4	3.0	0.07
Dead Sea	33	6	13	36	181	1	4.5[9]

Increases of salinity can cause marked increases in galvanic corrosion and a more rapid solution of carbonate and sulphate minerals. Such occurrences will be discussed later (*see* metals and stone). Salinity will also effect the amount of dissolved oxygen.

Dissolved Oxygen Content

The dissolved oxygen content of sea water is a function of the temperature, pressure, salinity, and biological activity. Its solubility increases with decreasing

[5] *Ibid* 17.
[6] R. A. Horne, *Marine Chemistry*, New York (1969), 146.
[7] *Ibid.* 156.
[8] *Ibid.* 200–1.
[9] J. H. White, A. El Yaniv, and H. Schick, 'The Corrosion of Metals in the Water of the Dead Sea', *Corr. Sci.*, 6, nos. 9–10 (1966), 449.

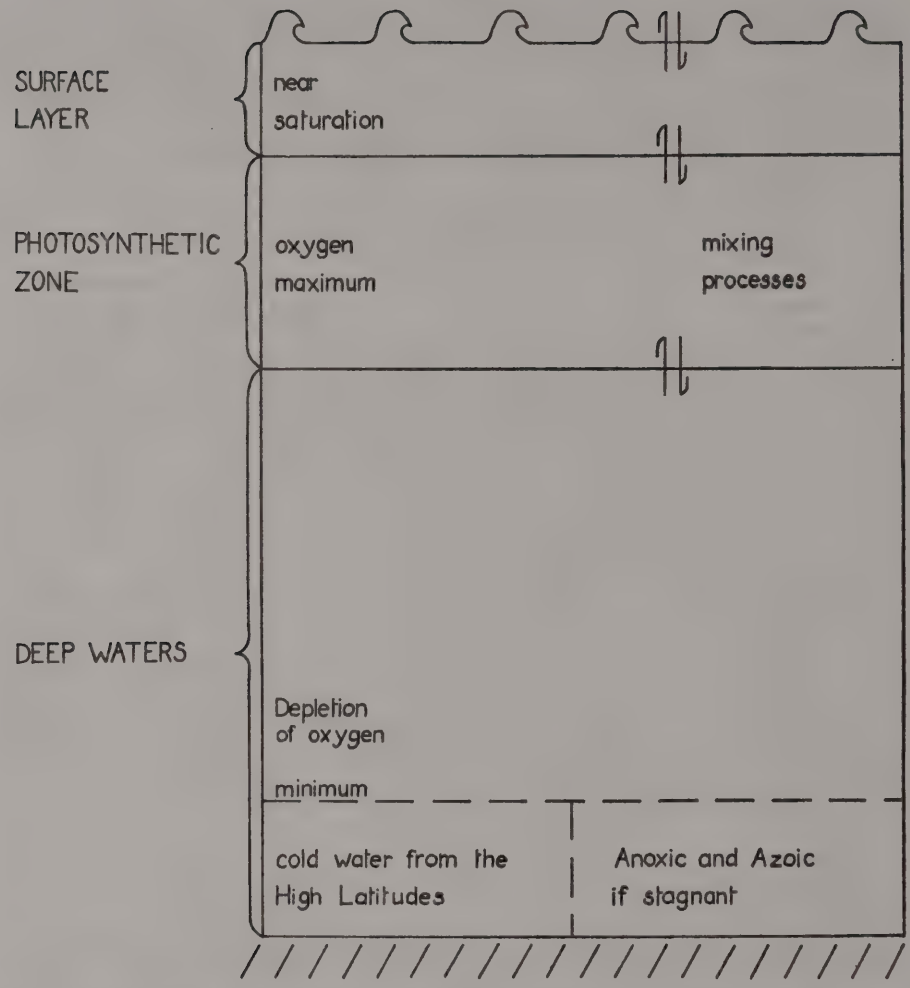


Fig. 1 Diagrammatic representations of the several conditions of dissolved oxygen content.[14]

temperature and decreasing salinity.[10] The surface layer is well mixed by wind and water movement and 'tends to be the saturation value established by the sea-air interface at the ambient temperature and barometric pressure. If the water column is relatively stable, a subsurface maximum in the concentration of dissolved oxygen is frequently observed somewhere in the first 50m as a result of 0_2 production by photosynthesis'.[11] Sufficient oxygen may be produced in the subsurface layer to increase the oxygen content from 10 to 20 per cent above the saturation value.[12]

[10] C. E. Zobell, *op. cit.*, fn. 1, 20.
[11] R. A. Horne, *op. cit.*, fn. 6, 199.
[12] H. Uhlig, ed., *The Corrosion Handbook*, New York (1948), 1119.

Below the photosynthetic zone waters can be oxygen-rich or anoxic depending on whether they are new cold waters from high latitudes or stagnant waters.[13] Such factors may influence particularly the rates of galvanic corrosion.

Pollution by domestic sewage or organic wastes greatly increases the concentration of organic derivatives such as nitrogen compounds and phosphates and may result in a marked deficiency in the oxygen concentration.[15] As the number of bacteria increases to deal with the breakdown of the nutrients so does their consumption of respired oxygen. Aerobic bacteria, in fact, probably consume more oxygen than all other organisms combined.[16] 'Because of the relatively large bacterial populations and high content of organic matter in bottom deposits, it is primarily in or immediately above bottom deposits that the most oxygen is consumed, likewise it is primarily in or near bottom deposits that other gases are produced or transformed by bacteria'.[17] This means that archaeological objects found on the sea bed may have been in an environment with little or no oxygen, depending on pollution, organic decay, microbiological activity, etc.

The Sea Bed

In the third volume of *The Sea*, A. S. Laughton[18] gives a classification of the bottom according to size.

Bed rock	in situ	Pebbles and granules ...	2–64 mm
Boulders	>256 mm	Sand	1/16–2 mm
Cobbles	64–256 mm	Mud (silt and clay) ...	<1/16 mm

For the underwater archaeologist whose wreck has come to rest on the bottom, it may be better to modify the classification and speak of a sea bed that is predominantly rock, sand, silt, or clay. While still being a physical qualification it separates some of the chemical differences:

Rock. A wreck which lands in a rocky area stands the greatest chance of physical break-up. The inevitable currents moving around the rocks will carry off much of the debris, while smaller objects may be washed into crevices where they are, on occasion, protected from physical break-up by over-covering sand.

Sand. A sandy bottom which is swept by currents can cause rapid erosion of anything in or above the shifting sand, one of the most erosive situations occurring when an object finds its way to a sandy bottom overlying bedrock. Resting on rock but only half buried in sand, it is exposed to the currents and shifting sand and deteriorates quickly.

Silt. Physically speaking, silt can be protective. Being of smaller grain size, it does not settle where there are strong currents; hence, objects found in silt will

[13] R. A. Horne, *op. cit.*, fn. 6, 221.
[15] H. Uhlig, *op. cit.*, fn. 12, 1119–1120.
[16] *Ibid.*, 198.
[17] *Ibid.*, 108.
[18] C. E. Zobell, *op. cit.*, fn. 1, 20.
[18] M. N. Hill, *ed.*, *The Sea III*, London (1963), 439.

probably not have suffered damage by water movement. If there is no chemical action on it, an object buried in silt should be well preserved.

Clay. Because of its colloidal properties and small grain size, clay binds tightly any object buried in it, any movement being almost completely restricted. Generally, however, artifacts will rest not in, but on top of, a clay bottom within an overlying fine silt layer. This was the case with the prehistoric dugout canoe found off the coast of Seasalter, Kent, in 1970. Silt in the area is being washed away by changing currents laying bare a number of old sunken craft which are resting on top of the London clay. In hard clays such as this the binding qualities of the particles may be such that even heavy objects do not break the bonds and sink into the clay.

CHEMICAL ASPECTS

Sea water is a buffered, very slightly alkaline solution and its pH ranges from 7.5 to 8.5. When in equilibrium with the carbon dioxide of the atmosphere, the pH of sea water ranges from 8.1 to 8.3. The removal of carbon dioxide by photosynthetic processes of marine plants increases the pH somewhat, an exceptional limiting value observed being as great as 9.7[19] although a pH of 8.3 to 8.5 during the hours of intense sunlight would be more usual. The decomposition of organic matter removed from the influence of the atmosphere decreases the pH. Values as low as 7.5 are observed at certain depths in the Pacific, where decomposition has almost entirely removed the dissolved oxygen. In marine bottom deposits, tide pools, bays, and estuaries, the pH may exceed 8.5 or fall below pH 7.0.[20]

Certain generalizations can be made about the pH of marine sediments: Pore-size of the sediment can sometimes be a general indication of the oxidation state, sandy bottoms allowing for water movement containing entrained air (resulting in a higher pH), while the finer grained sediments generally promote reducing, anaerobic conditions by the prevention of water circulation (resulting in a lower pH).[21] Colour is another indication: highly oxidized sediments are usually brown while the reduced acidic sediments vary from grey to green to black.[22]

Two factors which affect the colour are the amount of marine humus and the amount of hydrogen sulphide produced by bacterial activity. Marine humus is organic matter of a similar chemical nature and origin to that of soil humus. Its concentration on the sea bottom varies considerably: from 0.5 per cent in the case of sand bottoms to nearly 10 per cent in certain silt and clay bottoms. In some areas, such as protected harbours or fjords, the sediment may contain as much as 20 per cent humus.[23] Bacteria at work on the decaying marine humus not only consume oxygen (in the case of aerobic bacteria); they also produce reducing substances which greatly lower the pH, the most effective reducing agent being the sulphydril ion

[19] H. Uhlig, *op. cit.*, fn. 12, 1118.
[20] C. E. Zobell, *op. cit.*, fn. 1, 19.
[21] M. N. Hill,*op. cit.*, fn. 18 592.
[22] *Ibid.*, 592.
[23] S. A. Waksman, 'The Role of Bacteria in the Cycle of Life in the Sea', *Sci. Monthly*, 38 (1934), 48.

(HS^-).[24] The hydrogen sulphide produced, while lowering the pH, also darkens the sediments by reactions with metallic ions.

One should perhaps mention that the pH can vary greatly through the micro-environments of a sediment or that the sediment itself may have a specific pH profile: for example, there might be oxidizing conditions at the surface and reducing conditions below a depth of several feet[25] or even several inches. *Bacterial activity* is the most important single factor in establishing the micro-environment of the sea bed and its effects have been and will be mentioned often in the course of this paper. Let us take a look at how bacteria can effect the pH:

> The following microbiologically activated processes tend to increase the hydrogen ion concentration or to decrease the pH: (1) Production of CO_2 by respiring cells; (2) production of organic acids such as lactic, butyric, acetic, and formic acids, for example from the decomposition of carbohydrates, lipids, proteins, etc.; (3) oxidation of H_2S or sulfur to sulfuric acid or other acid sulfates; (4) reduction of sulfur to H_2S; (5) formation of nitrite or nitrate; (6) assimilation of ammonium as a source of nitrogen or its oxidation as a source of energy, and (7) the liberation of phosphate from organic compounds. The hydrogen ion concentration may be decreased or the pH increased by the following microbiological reactions: (1) Utilisation of CO_2 by either chemo-synthetic or photosynthetic autotrophs, chiefly diatoms and algaes; (2) oxidation or decarboxylation of the salts of organic acids such as formate, acetate, proprionate, lactate, etc.; (3) reduction of sulfate to sulfur or H_2S; (4) reduction of nitrate or nitrite, and (5) the formation of ammonia from nitrogenous compounds such as amino acids, proteins, urea, purine bases, etc.[26]

One would expect the greatest bacterial activity to be in coastal areas which receive land drainge. The interesting point is that studies have shown the numbers of bacteria to be far greater in the sediments while the numbers in the overlying water show less than usual. This is a result of sedimentation, the sediment particles carrying large numbers of adhering bacteria to the sea bed. Also 'in such places the precipitation and sedimentation of suspended matter are accelerated by flocculation which occurs where fresh water is mixed with sea water. . . . The majority of the bacteria are carried to the sea bottom very near the point of entrance to the sea.'[27]

Carbonate Precipitation

The Carbonate Buffer System. The chemistry of carbon dioxide in the sea is very complex due to the fact that carbon dioxide, unlike the other atmospheric gases, reacts with the sea water to form carbonic acid, H_2CO_3, which in turn dissociates to form CO_3^{--}, and HCO_3^-. At marine pH's most of the dissolved carbonate in sea water is in the latter form.[28] This constitutes the principal buffer system of the seas. The CO_2 content decreases as the pH increases there being no free CO_2 in solution in sea water more alkaline than 7.5, most of it occurring in combination as bicarbonates and carbonates.[29]

Should anything occur to increase the temperature or salinity or to raise the pH, carbonates will be precipitated—usually as calcium, magnesium, and/or strontium carbonate.

[24] M. N. Hill, *op. cit.*, fn. 18, 603–4.
[25] C. E. Zobell, *op. cit.*, fn. 1, 104–5.
[26] R. A. Horne, *op. cit.*, fn. 6, 221.
[27] *Ibid.*, 600.
[28] *Ibid.*, 85–86.
[29] C. E. Zobell, *op. cit.*, fn. 1, 19.

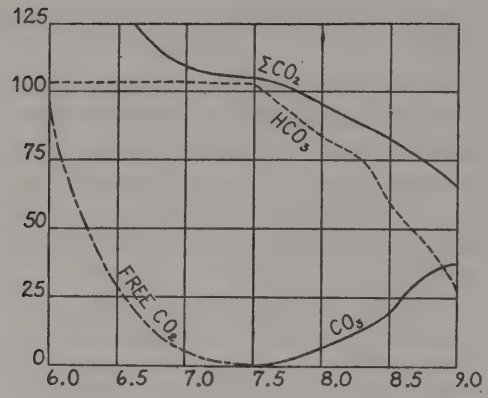


Fig. 2 Effect of pH on the relative concentration of free CO_2, HCO_3^-, CO_3^{--}, and CO_2 in sea water.[30]

Figure 3 taken from Horne[31] illustrates how the buffer system works. It does not show that the Mg^{++} and Ca^{++} ions are often extracted from the sediment, a fact which will be important to the discussion of the formation of concretions.

It is important to note that sea water is supersaturated with respect to $CaCO_3$. Below is a table showing the solubility products of certain salts in distilled water and in sea water (salinity of 35% at 20°C).[32]

Salt	*Distilled Water*	*Sea Water*
$CaCO_3$	0.5×10^{-8}	50×10^{-8}
$MgCO_3.3H_2O$	0.1×10^{-4}	3.1×10^{-4}
$SrCO_3$	0.3×10^{-9}	500×10^{-9}
$Mg(OH)_2$	1×10^{-11}	5×10^{-11}

Because of the influence of other ions on the activity of a given ion solubility products are much higher in sea water than in distilled water. But also because of the influence of other ions, the actual concentration of $CaCO_3$ is higher than the solubility product. The solubility product for $CaCO_3$ listed above was 50 x 10^{-8} while the concentration of calcium and carbonate ions in natural sea water (at pH 8.2) is 270 x 10^{-8}. This indicates that sea water is supersaturated in respect to this salt.[33]

Carbonate Concretions. Carbonate concertions often cover inorganic material which is retrieved from the sea. There are four ways in which these concretions may be formed:

(1) physically—by the growth of organisms on the surface of the object (cf. the discussion on pottery);

(2) physiochemically—by the solution and reprecipitation of carbonates (cf. the discussion on stone);

(3) electrochemically—by precipitation on the cathodic and anodic areas (cf. the discussion on metals);

[30] *Ibid.*, 20.
[31] H. Uhlig, *op. cit.*, fn. 12, 1119.
[32] R. A. Horne, *op. cit.*, fn. 6, 204.
[33] *Ibid.*, 1118.

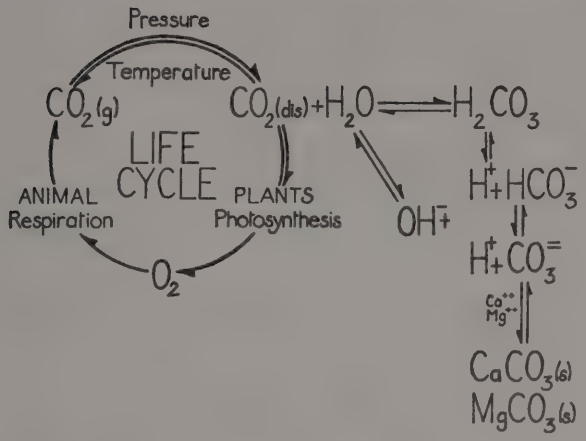


Fig. 3 The Carbon Dioxide-Carbonate System

(4) biochemically—by various micro-biological activities which ultimately lower the pH.

Bacterial Precipitation of Calcium Carbonate. Bacteria may influence the $CaCO_3$ equilibrium in four ways:[34]

(1) by their effect on the pH,

(2) by producing or consuming CO_2,

(3) by oxidizing organic salts,

(4) by assimilating calcium.

The sulphate-reducing bacteria play an important role in carbonate precipitation because they release H_2S into the environment which rapidly lowers the pH. A look at what happens in the process might be instructive for it is not just the sulphate-reducing bacteria but the reactions of their by-products with the by-products of photosynthesis. The following chart is adapted from a report on Lalou's work given by Kaplan:[35]

(1)

decomposition of organic matter
↓
formation of organic acids
liberation of CO_2
↓
decrease in pH
↓
solubilizes calcium from the sediment and causes an increase (often two-fold) in its concentration in sea water
↓

[34] C. E. Zobell, *op. cit.*, fn. 1, 103.
[35] M. N. Hill, *op. cit.*, fn. 18, 613–4.

(2) initiation of sulphate reduction
↓
increase in H_2S until sulphate disappeared
↓
decrease, then rise to original pH
↓
(3) CO_2 removed by photosynthesis
↓
further rise in pH
↓
precipitation of $CaCO_3$

In the initial phase bacteria cause the pH to be lowered. More calcium and carbon dioxide go into solution and then when the pH rises the calcium carbonate is precipitated. The overall reaction might be represented:

$$CaSO_4+CH_3COOH=CaCO_3+H_2S+H_2O+CO_2$$[36]

Concretions brought from the sea are often heavily stained by iron salts and researchers have found that the hydrogen sulphide released by the sulphate-reducing bacteria reacts with ferrous ions in the water or sediment to form iron sulphide which precipitates with the calcium carbonate.[37] This offers an explanation why often even pottery and stone (as well as metals like copper) can be covered with iron containing concretions.

Bacterial precipitation of carbonates can occur in other ways as well:[38,39]

(1) by the action of denitrifying bacteria, the hydrogen and carbon deriving from the anaerobic oxidation of organic matter.

$$Ca(NO_3)_2+3H_2+C=CaCO_3+3H_2O+N_2$$

(2) by the production of ammonia from protein or nitrate decomposition:

$$Ca(HCO_3)_2+2NH_4OH=CaCO_3+2H_2O+(NH_4)_2CO_3)$$
$$(NH_4)_2CO_3+CaCO_4=CaCO_3+(NH_4)_2SO_4$$

(3) by the bacterial oxidation of organic calcium salts:

$$Ca(COOCH_3)_2+4O_2=CaCO_3+3CO_2+3H_2O$$

Comments. The above description in no way purports to be a complete picture of the marine environment. Rather, an attempt has been made to mention those factors which generally affect the rate of deterioration of inorganic materials. Conditions such as light, temperature and water movement will probably change with the seasons altering the environment in a cyclical manner. Such alterations affect not only biological activity but also the rate of chemical reactions. The salinity of sea water can affect the rates of deterioration, as can variations in the oxygen content caused by pollution, organic decay, and biological activity.

The sea bed environment is first governed by its physical nature—rock, sand, silt, or clay—and then by its chemical nature: its pH resulting in part from the amount of decaying organic matter and bacterial activity.

[36] C. E. Zobell, *op. cit.*, fn. 1, 101.
[37] C. Lalou, 'Studies on Bacterial Precipitation of Carbonates in Sea Water', *J. Sediment Petrol.*, 49, no. 8 (1937), 191.
[38] C. E. Zobell, *op. cit.*, fn. 1, 101.
[39] *Ibid.*, 100.

The carbonate buffer system in the seas results in the formation of concretions. Certain aspects of their formation will be discussed under the headings of metals, stones, and pottery, but here emphasis has been placed on the role of bacteria in the formation of concretions.

The role of bacteria, in fact, may emerge as one of the most important factors in establishing the chemical conditions of the microenvironment and these, indirectly, may be one of the greatest influences on the kind and rate of deterioration of inorganic materials found in that environment.

STONE

Stone which finds its way to the sea bed suffers deterioration either by physical erosion or by chemical solution. But as stone is a strictly heterogeneous substance often containing a mixture of many minerals, rates of deterioration are difficult to assess. For example, the heterogeneity of sandstones is enhanced by the variations in the cementing material and the degree of cementation.[40] In addition, we have already seen how variable the sea bed environment itself can be and, despite its slight alkalinity, sea water is corrosive for many rocks due to its high salinity.[41]

Carbonates and Sulphates

The reduction rates of limestone, marble, and alabaster surfaces by solution are established by (1) the ionic concentration of the solvent, (2) the solubility of the mineral; (3) the water temperature; (4) the solvent motion; (5) the stone fabric, etc.[42]

Sea water is usually less corrosive to carbonates than natural waters due to the high calcium carbonate content already present in solution. But diluted, under-saturated harbour waters can become quite aggressive.[43] In addition, polluted waters can increase the solubility of stone to several times that in unpolluted waters,[44] as they usually have a higher salinity, while the decay or organic matter can release organic acids and H_2S creating acidic conditions.

Sulphates are far more soluble, the solubility rate of gypsum rock being estimated by Kieslinger to be 32 times higher than that of limestones.[45] The following table shows the solubilities of some common soluble carbonate and sulphate minerals (given in parts per million at about 20°C).[46] Solubility figures are averages.

Mineral (rock)	*Average: freshwater*	*Average: sea water*
calcite (limestone, marble)	40–85 rpm	66 ppm
aragonite (onyx marble)	11–16% more sol. than calcite	like calcite
dolomite (dolostone)	less sol. than calcite	50 ppm
siderite	10–25 ppm	no data available
gypsum (alabaster gyprock)	2000 ppm	6000 ppm
anhydrite (alabaster)	less than gypsum	5000–6000 ppm

[40] E. M. Winkler, 'Decay of Stone', *Conservation of Stone* (Reprints of the Contributions to the New York Conference on Conservation of Stone and Wooden Objects, London, 1970), 7–8.
[41] *Ibid.*, 5. [42] *Ibid.*, 8. [43] *Ibid.*, 5.
[44] *Ibid.*, 9. [45] *Ibid.*, 8. [46] *Ibid.*, 8.

All carbonate minerals increase their solubility with the increase of the CO_2 partial pressure in the solvent.[47] This results from either a decrease in temperature or an increase in pressure. Thus, theoretically, calcium carbonate on the sea bed at 99 feet (4 atmospheres or 60 lb/in^2) is more soluble than the same in surface waters. The solubility of sulphate rocks does not depend on the CO_2 concentration of the water and is only slightly affected by temperature, being somewhat more soluble at lower temperatures.[48]

An interesting piece of stone was found during the excavation of a Greek ship which sank off the coast of Kyrenia, Cyprus, in about 300 B.C. (Plate 1). It is a marble pedestal 53 cm. high covered with a concretion which varies in depth from ½ cm. to 1 cm. In section the surface of the marble is badly eaten away, the gaps being filled with concretion. The concretion effervesces in acid leaving behind a slight residue. Thus it is essentially carbonate. It is probable that solution of the calcium carbonate has occurred followed by reprecipitation on the surface. But the concretion itself is very porous having an appearance much like volcanic rock. This may be the result of the concretion having been formed while the object was buried in the sediment for there are often inclusions in the cavities. There are also skeletal remains throughout the concretion so that to call the entire concretion a result of physiochemical precipitation would be incorrect.

There are two other possibilities which may help explain the concretion's porosity. First is the possibility of once present organic growth having decayed and disappeared; the second has to do with organic coatings on precipitated calcium carbonate. Field observations in the Bahamas[49] have shown that precipitated calcium carbonate has a light thin film of carbohydrates a few molecules thick which protects it from chemical attack by sea water. Formation of this film during precipitation may effect the way in which the concretion is formed.

Most concretions on objects recovered from the sea are porous, those on iron being the most porous because of the rapidity with which they were formed. But one does not find this volcanic-type concretion in electrochemically precipitated or organically grown concretions, which makes one wonder if the key to the formation lies somewhere in the mechanism of physiochemical precipitation. It is a question which bears further investigation.

Silicates

According to Winkler, silicates do not dissolve but are leached and hydrolized to a softer, dull clay mineral. They do not go into solution like the sulphates and carbonates.

> Alkalies and iron are slowly removed while oxygen and water enter the now incomplete lattice to form hydroxides of aluminium and silicon. This results in a change towards an entirely new crystal lattice with very different and much less favourable physical properties than the original mineral of the fresh rock substance.[50]

[47] *Ibid.*, 8. [48] *Ibid.*, 8. [49] *Ibid.*, 5–6. [50] *Ibid.*, 8.

Winkler prefers to call this process 'dissolution' rather than 'solution' because the rock surface is not reduced as in pure solution but instead is softened and becomes more vulnerable to mechanical erosion.

Animal Acitivity

Animal activity can cause deterioration either chemically by the secretion of organic acids or mechanically by boring or digging. The following report on marine borers, is taken almost exclusively from Winkler,[51] any other sources being footnoted.

Borers in soft rock: These are found almost exclusively in clays or shales and drill mechanically by turning their sharp-edged shell. Included in this group are some angel wings (Pholas), the false angel wing (Petricola), and the piddock (Zirfaea).

Borers in carbonate rock: Animals which secrete weak acids can dissolve carbonate rocks quite readily, boring mussel shells or sea dates (Mytilus) being encountered the most frequently. Various species of angel wings (Pholas) are also known borers in limestone and are closely related to the well-known wood borer, the teredo worm.[52] Boring sponges (Clona and Alectona) infiltrate the surface to a depth of 2 or 3 cm. and convert it to a friable mass which crumbles as sand to the bottom. Winkler reports Newman's observations of extensive bioerosion in the subtidal zone of tropical Bermuda: erosion rates for the sponge Cliona lampa being 1.4 cm./year and for the boring clam Lithophaga 1.3 cm./year. Bioerosion in the intertidal zone was much less, the maximum observed being 1 mm./year. There was no bioerosion recorded in the spray zone above the intertidal zone. Boring annelid worms (Polychetes) often bore round or oval-shaped holes to a total depth of several inches.

Borers in hard rock: Sea urchins are the least selective of all marine borers as their activity is purely mechanical. Armed with a set of strong, sharp teeth, they are able to cut into any type of rock, leaving behind them a five-star pattern. Echinus and Eucidaris are the most common boring genera from the subarctic to the tropics, the boring rate of the echinids being as much as 1 cm./year in limestone, faster in weathered granite. A detailed bibliography on marine borers has been compiled by Clapp and Kunk for the Office of Naval Research (*Marine Borers.* Office of Naval Research ACR-74, 1963).

Higher animals: Boring clams, sponges, worms, and sea urchins are the most common of the rock boring organisms. Their sessile life in a protecting excavation forces them to enlarge their dugout as they grow. Boring animals generally live in colonies and stone which is attacked by them will show extensive perforation after only a few years.

Bacteria: The activity of bacteria in producing organic acids and the sulfhydril ion (HS^-) has already been discussed and its action on carbonate stone is obvious.

[51] *Ibid.*, 7.
[52] John J. Myers, *Handbook of Ocean and Underwater Engineering* (New York, 1969), 12.

Silicates are also broken up quickly by bacteria which invade only after the first stages of weathering are under way. The deterioration rate of silicates thus becomes progressively quicker with time.

Fungi: In the soil fungi are very active in the break-up of silicates. Very little is known, however, about the activities of marine fungi and their action on stone in the sea, if any, is unknown.

Comment: Stone artifacts raised from an archaeological site have been exposed to the sea bed environment for a very short time on the geological time scale. Consequently, many of them emerge with no apparent deterioration. Numerous stone anchors have been raised intact and some of the Kyrenia ship cargo, querns of vascular basalt, look as new as the ones which would have been unloaded in Kyrenia harbour the day before the ship sank.

At present it appears that marble (or limestone) and alabaster (or gypsum) artifacts are more likely to be found poorly preserved: marble, because of its possible involvement in the carbonate buffer system of the seas, and alabaster, because of the higher solubility of sulphate minerals. Other types of stone artifacts, found to date, seem to be in good condition. But marine archaeology is young and stone finds thus far are relatively few. Sympathy must be offered in advance to the conservator who will be handed a stone artifact riddled with holes made by marine borers!

POTTERY

Pottery found above the Sediment

Pottery protruding above the sediment or lying on top of it is subject either to erosion or to fouling by marine organisms. Erosion occurs by the action of water and shifting sand when the current is too strong to allow for the attachment of fouling organisms. Erosion also occurs in calm waters which for some reason—pollution, perhaps, or lower temperatures—have fewer numbers of fouling organisms. This applies to both glazed and unglazed wares.

Pottery covered in organic concretion is the more common find and a closer look at this concretion reveals many types of organisms which have left behind their mud homes, or calcarous or siliceous shells or skeletons. The following summary of fouling organisms is taken directly from Uhlig[53], any other source being footnoted:

Semi-motile fouling organisms

(1) Sea anemones and allied forms.

(2) Some of the worms which build more or less temporary, loosely adherent tubes of mud and sand for protection. These organisms frequently abandon their tubes (often 8 inches or more in length) and move to another location.

(3) Certain Crustacea, such as Corophium, build small temporary sand and mud

[53] H. Uhlig, *op. cit.*, fn. 12, 433–434.

tubes which they cement to material submerged in salt water. The tubes are quite adherent but their builders frequently abandon them, and move to other locations.

(4) Various molluscs, such as many of the numerous species of mussels, become firmly attached to any convenient base by means of a mat of very strong chitinous hairs. The tip of each hair becomes cemented to any suitable base, thus forming a dense mat on the surface, but these organisms are able to loosen their hold-fasts and migrate to new locations. When they die the mat of chitinous hairs remains firmly attached to the material last occupied.

Sessile organisms

This group cannot survive without becoming firmly attached to a suitable base.

I. Organisms which build hard calcareous or chitinous shells (Plate 2):

(1) Annelids, which form coiled or twisted tubes.

(2) Barnacles, which construct cone-shaped shells built up of laminated plates:

(3) Encrusting Bryozoa, colonial animals which form flat, spreading, multicellular, coral like patches.

(4) Molluscs of several species, i.e. oysters and mussels.

(5) Corals.—As coralline growth in the tropics can be so massive perhaps a word more should be said about its nature: 'Coral is composed of the shells, tests, hard parts, and skeletons of a variety of marine invertebrates and plants. Chief among these are (1) the coralline plants; (2) corals, which are invertebrate animals related to jellyfish and sea anemones; (3) molluscs of many kinds; (4) foraminifera, single-celled invertebrates with mostly calcareous tests; and (5) a variety of other forms of less consequence. Coral makes up the bulky frame-work of many reefs, and the other forms make up the matrix. Coralline algae, in particular, may cement the whole mass together into a very porous rock. . . . In general, reefs can be expected to be almost pure calcium carbonate of low density and high porosity. Recemented calcium carbonate, somewhat higher in bearing strength, hardness, density, and of lower porosity, is also common. The latter may even be silicified in places owing to complex physio-chemical factors in the decomposition, recementation, and percolation (however slowly) of water through the structure.'[54]

II. Organisms without hard shells

(1) Marine algae: green, brown, or red filament growths (such as Ceranium, Fucus etc.).

(2) Filamentous Byozoa: fern-like or tree-like growths.

(3) Coelenterates (hydroids) such as Tubularia, with stalk-like or branching growths, each branch terminating in an expanded tip.

[54] John J. Myers, *op. cit.*, fn. 52, 41–42.

(4) Tunicates (sea squids): soft spongy masses.

(5) Calcaerous and siliceous sponges.

Fouling usually begins with the arrival of marine bacteria or other unicellular marine organisms. They form a thin film which provides a favourable foothold for macro-organisms[55] which themselves are commonly in the minute larval or undeveloped juvenile form. These fouling organisms secure a foothold in a manner characteristic to their particular group:[56] many species of the algae secure a firm attachment by exuding a mucilaginous material which hardens to a glue-like consistency. As the plant grows, root-like growths spread over the surface of the pot, greatly increasing the firmness of the attachment. Hydroids act in a similar manner. Other groups such as barnacles and some of the molluscs, excrete a calcareous material while with yet others the cementing material is of a siliceous nature. A hard, smooth surface provides a firmer footing than a soft material[57] which is one reason one often finds pottery more heavily covered with organic concretion than, say, nearby rocks.

Glazed pottery which is above the sediment will usually be covered by fouling organisms fairly quickly. They help to protect the glaze by slowing down the diffusion of ions. A glaze so protected may suffer little damage despite the fact that it is in a slightly alkaline medium of sea water.

Pottery Found Within the Sediment

Pottery found within the sediment will not be covered by concretions of marine fouling organisms.

In fact, it usually immerges intact. This can, of course, vary according to the acidity of the sediment and the type of filler. Theoretically, there is always the possibility of solution and reprecipitation, and if the sediment is very acidic, loss of filler may occur.

Glazes will deteriorate in a manner similar to glass, much depending on the nature of the sediment. Sulphate-reducing bacteria have been known to blacken lead glazes both in the sediments and under concretions. George Bass reported blackening of the surface of much of the concreted pottery found at Yassi Ada.[58]

Comments. Although the subject of this paper is 'deterioration of inorganic materials under the sea', I should just like to mention some of the problems encountered when pottery is 'topside': Soluble salts are not a problem with pottery as long as it is on the sea bed as they are always in solution. But once the pot is raised crystallizing salts can rapidly cause damage and care must be taken to remove them to avoid blistering, flaking, cracking, or loss of glaze.

Concretions may come off causing no damage to the pot but very often the surface of a coarse-bodied pot will suffer slight damage if removal is done

[55] H. Uhlig, *op. cit.*, fn. 12, 435.
[56] *Ibid.*, 439.
[57] *Ibid.*, 439.
[58] George Bass, Personal Communication, June, 1970.

mechanically. This is because the concretion has penetrated superficially into the open pores on the surface of the pot and when the concretion is removed, the surface layer powders away.

Usually concretions can be removed safely from glazed pottery but much depends on the condition of the glaze and the body of the pot. Glazes have generally been found in good condition but sometimes the body of the pot is friable or powdery, making the removal of the concretion without removing the glaze almost an impossibility. Siliceous concretions are extremely tough and very difficult to remove.

GLASS

Ion Exchange

At present the decomposition of glass is imperfectly understood but most glass technologists will agree that it is essentially a preferential leaching and diffusion of alkali ions across a hydrated, porous silica network. Let us first consider a theoretical simple sodium silicate glass in pure water: It has been contended that sodium ions are removed and replaced by hydrogen ions which diffuse into the glass to preserve the electrical neutrality as the sodium ions diffuse out.[59] The silicates are converted into a hydrated silica network through which the diffusion occurs. A simple drawing may illustrate what is happening (fig. 4).

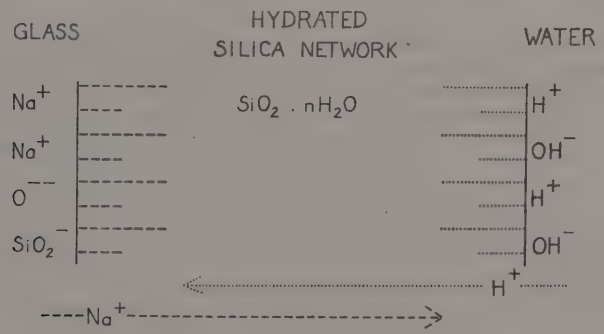


Fig. 4 Ion diffusion, initial stage.

To begin with the concentration gradient will have an abundance of Na^+ ions at the glass-leached layer interface and an abundance of H^+ ions at the leached layer-water interface. But as the diffusion continues these conditions will slowly reverse (fig. 5). At the boundary between the leached layer and the solution, surface sites will be available to cations which may be occupied by one of the ions in solution.[60] If Na^+ ions occupy these surface sites, the transport of sodium ions through the leached layer will be retarded because the boundary concentration is increased.

[59] L. Holland, *The Properties of Glass Surfaces* (London, 1964), 135.
[60] R. W. Douglas and T. M. M. El-Shamy, 'Reactions of Glasses with Aqueous Solutions', *Amer. Cer. Soc. J.*, 50, 1 (1967), 5–6.

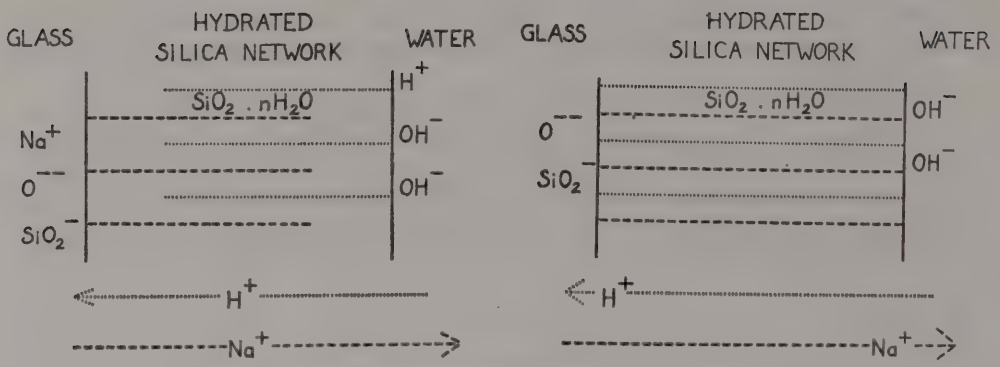


Fig. 5 Ion diffusion, intermediate stage and final situation.

Also, as the number of H^+ ions at the leached layer-solution interface decreases, the rate of H^+ ion diffusion may start to slow down. But at the same time, the loss of H^+ ions from solution will cause a rise in pH at the leached layer-water interface. As the pH increases, there is a tendency to form silicate ions with a consequent increase of hydroxyl groups around the silicon atoms.[61] This removes the free hydroxyl ions from solution and the cycle begins again. Douglas and El Shamy summarize the present stand:

> Although discussion of the decomposition of glass has been simplified in terms of diffusion through a siliceous layer and of the occupancy of the surface sites by either hydrogen ions or alkali ions as though these were clearly separable processes, they in fact occur simultaneously. During the reaction, the concentration gradient of the diffusion process is determined by the variation of the diffusion coefficient with concentration and by the boundary conditions, i.e., the concentration at the glass-leached layer boundary and at the leached layer-solution boundary. The latter is determined by the occupancy of the surface sites and above a critical pH the concentration of hydrogen ions in solution is so low that the sites begin to be occupied preferentially by alkali ions, increasing the concentration of the alkali ions at this boundary and tending to slow the diffusion process. It does not, however, halt it, because the removal of the silica into the solution increases as the pH rises and this has the opposite effect on the diffusion process, tending to decrease the width of the siliceous layer. Furthermore, the removal of silica brings alkali into solution at a rate depending on the rate of removal of silica and the occupancy of surface sites.[62]

The above description has been for a theoretical simple sodium silicate glass. But glass invariably contains modifiers which act as stabilizers such as the basic oxide, CaO, and these stabilizers are also likely to be involved in ion exchanges. An interesting discovery was made on glass retrieved from the harbour at Port Royal, Jamaica: Studies at the Corning Museum of Glass revealed that there had been a 'substitution of MgO for CaO on an almost equimolar basis'.[63] No suggestion was given as to why the ion exchange had occurred but several possibilities may be worth mentioning. (1) First of all, one must recall that in the buffer system of the

[61] L. Holland, *op. cit.*, fn. 59, 138–139.
[62] R. W. Douglas and T. M. M. El-Shamy, *op. cit.*, fn. 60, 7.
[63] R. H. Brill and Sheldon Moll, 'The Electron-beam Probe Microanalysis of Ancient Glass', *Recent Advances in Conservation* (London, 1963), 151.

ocean, calcium ions are extracted from the sediment into the surrounding water. This was discovered by Lalou[64] in his experiments on carbonate precipitation. He found that while there was 'a considerable increase in the concentration of the Ca (from about 0.44 gm./litre to 0.85)',[65] there was an insignificant increase in magnesium into the water. Whether this phenomenon could effect the mobilization of calcium ions in glass buried in the sediment is open to speculation. (2) A Ca^{++}—Mg^{++} ion exchange is a common occurrence on the surface of carbonate minerals.[66] But there is a bonding preference for Ca^{++} over Mg^{++}. Whether this fact could have any effect on the mobilization of Ca^{++} ions in the glass is also perhaps a possibility. No matter what causes the ion exchange, the very fact that it does occur poses an interesting problem: In what way is the stability of a glass affected by a CaO—MgO exchange?

Decomposed glass often appears as laminated, irridescent layers on top of the undecomposed glass and, according to present theories, these layers should be nothing more than a very porous hydrated silica network. But there are two puzzling bits of information which are not in accord with this theory. First were the experiments done by Guillot[67] in the 1930's. He filled a glass test tube with a saturated solution of sodium bicarbonate in water. He then removed the decomposed layers which had formed as a skin on the inside of the test tube and put hydrochloric acid on them.

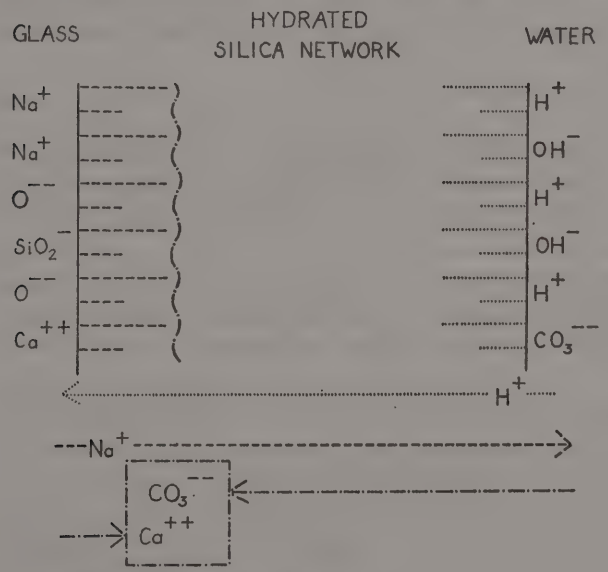


Fig. 6 The results of diffusion when calcium carbonate ions are present.

[64] C. Lalou, *op. cit.*, fn. 37, 192.
[65] *Ibid.*, 192.
[66] R. A. Berner, 'Diagenisis of Carbonate Sediments: Interaction of Magnesium in Sea Water with Mineral Grains', *Science*, 153 (1966), 190.
[67] M. Guillot, 'On the iridescence of antique glass. Formation of the solution of bicarbonates by the rhythmic precipitation of calcium carbonate', *Comptes Rendus*, 193 (1934), 2094–5.

The fizzing indicated carbonate and according to his observations it came from *between* the layers of silica. Analysis of the hydrochloric acid revealed iron, some strontium, but, above all, large quantities of calcium. He concluded that $CaCO_3$ had precipitated when the Ca^{++} ions diffusing out of the glass met with the CO_3^{--} ions diffusing into the glass. And this would be possible even in a mildly acidic or neutral solution, if the above description of the ion diffusion and exchange were accepted and if the cyclical change in the diffusion gradient were true. As the diffusion process slowed down, conditions would be more alkaline at the glass-leached layer interface, and would be right for $CaCO_3$ precipitation. Again, I offer this only as an unqualified guess.

Guillot did his analysis by chemical means but recently more sophisticated techniques have been used with similar findings. Shaw[68] discovered with the use of an electron microprobe that the 'concentration of silicon and calcium was observed to rise and fall with a remarkable and repeatable periodicity'. He used this finding to count the layers of decomposed glass, a dating technique which will be discussed later. These findings make us wonder what role, if any, carbonates might play in the formation of the layered structure. It is not a topic which is discussed in the present literature and is worthy of further examination.

Other ions are also found precipitated in the crusts but these appear to enter with the attacking solution through cracks and channels in the weathered crust. The most common are iron and manganese which stain the iridescent layers deep red-brown or purple.

Factors Effecting Decomposition

The rate of decomposition is effected by four main factors:[69] (1) the composition of the glass; (2) the composition (particularly the pH) of the attacking solutions; (3) the temperature, and (4) the time. For glass retrieved from the sea bed, one might add a fifth; (5) the pressure.

(1) *Pressure*. Pressure can increase the rate of diffusion of ions and has been used in an accelerated test of glass decomposition. In the particular test 4 atm pressure was maintained in an autoclave.[70] The same pressure would exist at a depth of 99 feet in the sea.

(2) *Temperature*. The same experiment also used high temperatures to accelerate the decomposition, the present literature saying that the rate of diffusion doubles with every increase of 10°C. Recent experiments by Brill, however, suggest that for certain temperature-ranges, the increase might be much greater.[71]

(3) *Time*. Increased pressure and temperature were used to accelerate artificially

[68] G. Shaw, 'Weathered Crusts on Ancient Glass', *New Scientist*, 27 (1965), 291.
[69] R. G. Newton, 'The Enigma of the Layered Crusts on Some Weathered Glasses, a Chronological Account of the Investigations', *Archaeometry*, 13, 1 (1971), 7.
[70] *Ibid.*, 2.
[71] Robert H. Brill, Personal Communication, 20th January, 1971.

the time factor. Obviously, the longer glass is exposed to corrosive conditions, the greater its chance of decomposition.

(4) *Composition of the glass.* The composition of a glass will determine its stability; in general the greater the proportion of CaO (or like modifiers) to Na_2O (or K_2O) the more stable the glass. However, if a glass containing large amounts of CaO does deteriorate, the CaO will be leached along with the Na_2O and the remaining silica may be so small a proportion as to be unable to maintain the bonds, and the glass will disintegrate. George Bass described some glass beads brought up from an underwater site which upon drying 'exploded into powder'.[72] The above description may offer an explanation.

The alkali/silica ratio is also important: the greater the percentage of silica, the less the tendency for it to be extracted, the reverse being true for the alkali.[73]

(5) *The composition of the attacking solution.* The composition of the attacking solution is probably the most variable of the factors, for the conditions of the environment are rarely stable, even, as we have seen, in a marine sediment. One must always consider, for example, such things as the frequency of replenishing the attacking solution: sediments with tight pores (such as clay) allow little water percolation which may limit the amount of ions available at the leached layer-solution interface and thus slow down the ion diffusion across the leached layer. But the main consideration is the pH and its possible variations.

Glass retrieved from an *acid environment* very often has the iridescent film which we know now to indicate the leached silica layers. The alkali which diffuses out is neutralized by the acid and few hydroxyl ions are available for reaction with the silica, the result being an increasing thickness of the silica layer as the alkali leaches out and the silica remains as a hydrated network. The increasing thickness of the silica layer will eventually slow down the diffusion process. Something must then occur to restart the cycle but just what happens next is as yet unanswered and is the subject of much debate at the present time. Some authors speak of the layer becoming compacted or 'gelatinized' while others look for a cyclical change in the environment. All that can be said for the moment is that glass in an acid environment forms iridescent layers of hydrated silica and that these layers appear to be formed as a result of diffusion of alkali across the layer in some sort of cyclical manner.

Glass retrieved from an *alkaline environment* is less likely to have the layered weathered effect. This is because hydroxyl ions are available for reaction with the silica network and, as the silica layer would not increase in depth, the rate of diffusion of the sodium ions need not be effected. 'Normally a protective layer does not form on silicate glasses attacked by alkaline solutions and the dissolution proceeds at a

[72] George Bass, Personal Communication, June, 1970.
[73] R. W. Douglas and T. M. M. El-Shamy, *op. cit.*, fn. 60, 3.

constant rate.'[74] Always, however, alkali ions are extracted in excess of the silica, leaving an alkali-deficient leached layer which continually moves into the glass.[75]

Dating of weathered glass

One particularly interesting example of weathered glass is a wine bottle recently recovered from the bottom of the sea off Port Royal in Jamaica. It is difficult to explain why this bottle should have a stratified weathering crust; nevertheless, a count of the layers in the crust indicated it has been submerged since 1691 plus or minus five years, and the historic fact is that part of the city of Port Royal sank into the sea during an earthquake in the year 1692.[76]

When Robert Brill first published his report in 1961, needless to say, it caused quite a stir, and it is a highly controversial but unsolved debate. Brill described dating successes not only with glass retrieved from the sea, but from the soil as well. What controlling factor(s) could cause the yearly formation of a weathered layer? Presumably if one layer is formed each year, the controlling factor is more likely to be a result of the environment: some environmental periodic change which affects the growth of the weathered layer. Brill hypothesized that variations in temperatures in the marine sediments, i.e., the mean summer temperature compared to the mean winter temperature, might be enough to affect the decomposition process. The temperature variation in the Port Royal sediment is now known to be more than 4°C. As for the samples from the soil, Brill suggested that an abundance of water in the warm summer months might be sufficient to affect the weathered layers:

Although the mechanism of the hydrolytic attack of glass has not been completely elucidated, it almost certainly involves a selective leaching of 'the more soluble ingredients', principally the alkali metal oxides, leaving a hydrated residue of high silica content. On the basis of the results of this investigation, it seems reasonable to postulate that any appreciable and prolonged variation in temperature or availability of water seems to be accompanied by an irreversible change in the structural state of the siliceous residue. This structual change apparently persists even after the original conditions are restored, thus forming a discreet individual layer. Since the layer formed is porous, water may diffuse through from the surroundings during the next 'active' cycle and renew the hydrolytic attack on the body of the remaining glass.[77]

But there are many who take a stand different from Brill's and among them is R. G. Newton whose recent publication in *Archaeometry* summarizes the work done to date on layered crusts of weathered glass.[78] He points out that the accelerated growth of weathering layers has been achieved under constant conditions with time being the only variable. Ten weathering layers were produced on a glass of high alkali content which was exposed to the action of CO_2-free steam in an autoclave for 4 hours at 4 atmospheres pressure.[79] He also cited a group of glass sherds which

[74] L. Holland, *op. cit.*, fn. 59, 130.
[75] R. W. Douglas and T. M. M. El-Shamy, *op. cit.*, fn. 60, 5.
[76] Robert H. Brill, 'Ancient Glass', *Sci. Am.*, 209 (1963), 130.
[77] Robert H. Brill and Harrison P. Hood, 'A New Method for Dating Ancient Glass', *Nature*, 189, 4758 (1961), 13.
[78] R. G. Newton, 'The Enigma of the Layered Crusts on Some Weathered Glasses, a Chronological Account of the Investigations', *Archaeometry*, 13, 1 (1971), 1–9.
[79] R. G. Newton, *Ibid.*, 2.

had apparently been buried in close association for about 430 years and exhibited markedly differing weathering phenomena:

> In one group the sherd had thick weathered crusts containing contorted layers which could not be counted satisfactorily. The surfaces of the sherds in the other group seemed to be almost unaffected and there were few, if any, intermediate types. Chemical analyses of the unaltered glasses failed to reveal a clear explanation for the differences in behaviour.[80]

Newton does cite examples where the counting technique has given the correct number of layers, one of these being with the use of the electron microprobe described earlier. By counting the layers of silica between the layers of calcium with the electron microprobe the researcher was able to count about 700 layers on the weathered crust of a medieval linen smoother. The piece could therefore be 'dated' to the middle of the thirteenth century in good agreement with the associated pottery.[81] But Newton feels that it is more likely to be a coincidence than any other reason and concludes:

> Thus the enigma persists, or perhaps it has become even worse! Accelerated layering can be produced under unvarying conditions in an autoclave and 'annual' layering can be produced under the apparently unchanging conditions of Port Royal Bay. But most of the archaeological material does not have anything like enough layers for the numbers of years of burial. My own view is that the layers have nothing to do with the movement of the Earth around the Sun, but they are produced by some physico-chemical process at a fairly constant rate which is generally much less than one per year. Occasionally the rate is as fast as one per year (less than 20 samples altogether) but, at least at normal temperatures, the rate of formation does not seem to be faster than one per year.[82]

But Brill is the first to agree that the technique is not always applicable:

> . . . this technique . . . is not a general technique that can be applied to great numbers of ancient glasses. The simple fact is that there are relatively few ancient glasses which are sufficiently susceptible to the deterioration that they weather in such a way that one can see layers large enough to count. Among these, not all weathering crusts are firm enough to have survived and to be mounted, polished, etc.[83]

There is also the problem of being sure that the weathered surface is intact and that none of the layers has been lost during burial or excavation.

Brill's argument is intriguing but not very convincing, especially with regard to temperature variations being the controlling factor in the growth of the layered structure in marine sediments. But there are several points which Brill—and Newton—failed to mention which might relate to the subject.

First of all the sediment at Port Royal from which the glass was retrieved was said to be dark blue and it was mentioned earlier that such sediments tend to be reducing and have a large amount of marine humus. It was also mentioned that most bacteria are found very near their point of entrance to the sea, i.e. near shore. It is within reason, then, to assume that the glass was in a reducing sediment where

[80] R. G. Newton, 'Some Further Observations on the Weathering Crusts of Ancient Glass', *Glass Technology*, 10 (1969), 40.
[81] R. G. Newton, *op. cit.*, fn. 78, 5.
[82] *Ibid.*, 8.
[83] Robert H. Brill, Personal Communication, 20 January, 1971.

there was a good possibility of bacterial action. This would suggest an acidic environment which is in accord with the type of environment in which one would have expected to find a heavily weathered piece of glass like the one in question.

We have mentioned that bacterial action can have a seasonal effect on the pH of a sediment, conditions being more acidic in the autumn and winter as a result of the decay of organic matter. Could such conditions be enough to effect the diffusion processes and thus produce annual layers? Brill never mentioned it nor, for that fact, did Newton. Newton could not explain why some sherds from a site were heavily weathered while others in close proximity were unaltered. Could it have been caused by localized bacterial activity in the micro-environment?

There is another possibility which might have strengthened Brill's argument. There is a very definite silicon cycle in the sea which 'exhibits a strong seasonal dependence reflecting the waxing and waning of the life processes'.[84] Silicon dissolves at a fairly constant rate into sea water over the winter months but in the spring the growing phytoplankton populations extract vast quantities of silicon from the water. Dissolution from the sediment is immediately increased (at a time when the bacteria are least active and thus theoretically when the pH is the highest). The removal of silicon from the sediment slows down over the summer as the growth rate slackens. There is often a short second spurt of phytoplankton growth around September[85] but then the organisms die and fall to the sea bed replenishing the supply of silicon to the sea bed at a time when the bacteria in the sediment are the most active and the pH of the sediment is most likely to be at its lowest.

From these facts one can assume that silicon is being removed more quickly from the sediments at a time when the pH should be at its highest (spring and early summer) and is given back to the sediment at a time when the pH should be at its lowest (autumn). Theoretically, then, could it be possible that such factors might effect the diffusion of alkali and silicate ions in glass buried in the sediment, silicate ions being affected in the spring and alkali ions being affected in the autumn? The suggestion is not any less convincing, I think, than Brill's suggestion that temperature is the controlling factor.

But no theory of the annual formation of weathering crusts will ever be convincing unless it explains not only the soil-excavated but also the sea-retrieved glass by the same phenomenon, for the weathering products are too much alike. Granted, they are not always identical for, as Brill has found, soil-excavated weathered layers seem to be physically separated thin sheets while the crust from sea-retrieved glass occasionally appears as a 'physically intact body and the layers seem to be more like discontinuities within that body'.[87] Is this difference in appearance the result of a different kind of weathering or is it the result of some factor such as pressure

[84] R. A. Horne, *op. cit.*, fn. 6, 233.
[85] *Ibid.*, 233.
[86] *Ibid.*, 234.
[87] Robert H. Brill, 'The Scientific Investigation of Ancient Glasses', *Proc. Eighth International Congress on Glass* (1969), 66.

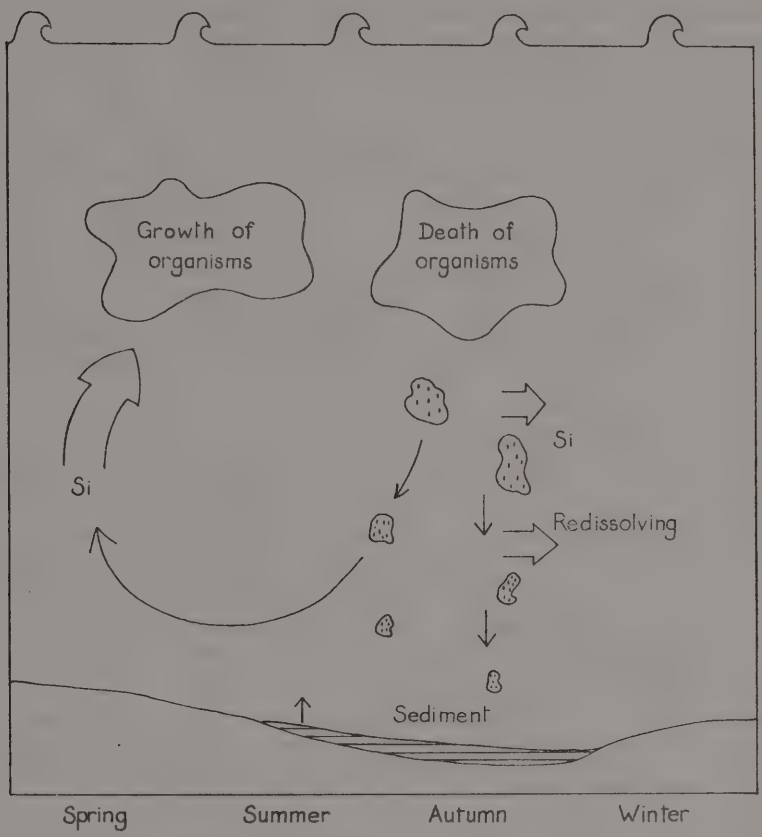


Fig. 7 Silicon Cycle of the Sea.[88]

or continual submersion? It is a question which bears further investigation. Indeed, the entire question of glass deterioration bears further investigation, for most of this chapter is unproved theories—some qualified, some unqualified (i.e., the writer's). It is hoped, however, that the presentation offers some food for thought.

METALS

Metallic objects on or in the sea bed are subject to the same laws of galvanic corrosion as those buried in soil (except for the fact that in sea water lead and tin are reversed in the galvanic series).[88] However, there are two things which often tend to make sea-retrieved metallic objects easily recognizable. The first is the strong smell of sulphur which often results from objects having been subject to the action

[88] H. Uhlig, *op. cit.*, fn. 12, 416.

of sulphate-reducing bacteria or polluted waters, and the second is the concretions which are either electrochemically or organically formed.

Concretions

Although galvanic action in sea water follows the general laws of galvanic corrosion, 'calcium, magnesium, and strontium present in sea water tend to precipitate as carbonates on the cathodic surfaces. The effect of such precipitated deposits, plus heavy growths of marine organisms, is to stifle the galvanic effect and to distribute the galvanic protection over larger areas of cathodic surfaces than would be the case in their absence. Marine growths also tend to distribute galvanic action over the anodic surfaces by interposing a common resistance which reduces the relative importance of the initial resistance of the electrolyte'.[89] Some examples of the type of situations that occur are given in Uhlig:

> Effects of encrusting materials on corrosion. Physical factors. The first spot of cementing material enlarges as the animal grows. With the oyster, the organic lime deposit may form a tightly adherent base which covers an area of several square inches. If the base is equally adherent to a metal over the entire area, this base may be expected to protect against corrosion. If the surface is uneven, and water penetrates, there will be different oxygen concentrations at points under the lime base and elsewhere on the surface of the metal. Oxygen concentration cells may then accelerate corrosion. . . . It also may be caused by one or more micro-organisms, such as diatoms or Foraminifera, having become attached to a portion of the area over which the macro-organism grows. Any uneven growth of micro-organisms on a portion of the metallic surface over which a macro-organism extends its base may result in unequal adherence of the latter. Because of this unequal firmness of attachment beneath some portions of the base, oxygen concentration cells may develop, resulting in corrosion.
>
> Chemical factors. Another entirely different and very important type of corrosion is encountered when, in the process of expansion of the base by growth, an organism completely surrounds and covers a later arrival, or smaller organism. The covered organism quickly dies. Degeneration sets in, followed by the probable production of hydrogen sulfide. An acid condition results which causes accelerated corrosion.[90]

But, generally, the concretion formed on metallic objects is not organic in nature but is more the result of electrochemical precipitation. The increase in pH around the cathode of a galvanic cell causes calcium and magnesium carbonates and hydroxides to precipitate on cathodic surfaces.[91] They form the matrix on which much skeletal debris is often cemented. An interesting study was done on the concretion of a Byzantine iron nail (7th century) from a shipwreck off the coast of Turkey. Examination at the Woods Hole Oceanographic Institute revealed that:

> The outer half of the concretion is dominated by calcium carbonate. A cohesive but porous aragonite matrix encloses carbonate skeletal debris containing, in decreasing order, benthic foraminifera, mollusk, algal, and echinoderm fragments; elongate aragonite needles grow from many of the skeletons. Aragonite and displaced calcite constitute over 90 per cent of the total material. The remainder is chiefly quartz, limonite, and pryite. . . . The carbonate encrustation . . . appears to result chiefly from inorganic precipitation of aragonite (possibly some calcite), and siderite to form a cementing matrix. A reasonable mechanism for this precipitation involves the corrosion of iron according to the generally accepted system:

[89] *Ibid.*, 418. [90] *Ibid.*, 440. [91] *Ibid.*, 1119.

$$\text{Anode} \quad Fe^0 \rightleftharpoons Fe^{+2} + 2e^-$$
$$\text{Cathode} \quad \tfrac{1}{2}O_2 + H_2O + 2e^- \rightleftharpoons 2OH^-$$

The rise in pH at the cathode and the consequent increased carbonate activity promotes supersaturation and inorganic precipitation of calcium carbonate. Soviet workers have found that in electrochemical induration of continental sediments calcite and magnetite precipitate at the cathode, while limonite forms at the anode. Since the electrochemical cells in the corroding nail form at the molecular level, no physical differentiation can probably be made between anodic and cathodic precipitation.[92]

The above description refers to the concretions on an iron nail so the reference to magnetite and limonite being precipitated at the cathode and the anode does not seem unusual. The fact is that iron corrosion products are often found in the concretions of metallic objects which contain no iron. This is because iron corrosion products in the solution precipitate out usually on the anodic surfaces and contribute to the growth of the concretion. This fact, which was mentioned in the introduction, is put to good use by marine engineers: not only is an excess of $CaCO_3$ introduced into pipes or condenser tubes (usually brass) and the pH adjusted so as to have a layer of $CaCO_3$ deposited,[93] but iron corrosion products are also introduced to make sure that the scale formed is continuous. It was found that the scale formed on brass condenser tubing was not continuous and resulted in severe pitting until iron corrosion products were introduced.[94]

The formation of concretions on metallic objects can inhibit corrosion in three ways: '(1) by forming a physical barrier to the diffusion of oxygen to the surface; (2) by increasing the thickness of the water layer on the wetted surface and thus increasing the oxygen diffusion path, and (3) by impeding the diffusion of cathodically formed alkali away from the surface.'[95] However the permeability of the concretion will depend to a large extent on the speed with which the concretion was formed and thus largely on temperature. The concretion formed in cold water is generally thinner and more continuous than one formed in warm water,[96] so that, although concretions form more quickly in warm water, they are likely to be more porous and allow for easier diffusion of ions and more extensive corrosion beneath them. Those formed in cooler waters will be more compact and diffusion is more likely to be hindered.

It should also be noted that iron forms the most voluminous concretions, followed by copper and silver. Lead does not form inorganic concretions.

Micro-organisms

In most instances micro-organisms contribute to corrosion but one case of protection occurs when micro-organisms form a slime on the surface of a metal in

[92] J. D. Milliman and F. T. Manheim, 'Submarine Encrustation of a Byzantine Nail', *J. Sediment. Petrol.* (Sept., 1968), 950–1.
[93] H. Uhlig, *op. cit.*, fn. 12, 502.
[94] R. May, 'Condenser Tube Corrosion. Some Trends of Recent Research', *Trans. Inst. Marine Engrs.*, 49, 8 (1937), 176.
[95] R. Holland and L. J. E. Sawyer, 'Cathodic Protection of Water-line Areas', *Brit. Corr. J.*, 1, 7 (1966), 269.
[96] H. Uhlig, *op. cit.*, fn. 12, 72.

contact with fast-moving waters. High velocities greatly increase the rate of corrosion and prohibit macro-organisms from attaching themselves to the surface. Microbiological slimes, however, can be formed and allow for the attachment of macro-organisms which otherwise could not gain a foothold. This sets up a barrier which can protect the metal from high velocity waters.[97]

But this same microbiological film (a numerous variety of organisms, including the slime-forming bacteria, fungi, algae, protozoa, diatoms, and bryzoa) more often increases the corrosion rate by 'maintaining concentration gradients of the dissolved salts and gases of the electrolyte in contact with the metal. The maintenance of such a microbiological barrier results in the establishment of differential effects which contribute to the corrosion of the underlying metal. Frequently beneath these barriers the concentration of oxygen is reduced to a value which permits development of anaerobic sulphate-reducing micro-organisms . . . (and it) may be significant that even in many aerobic waters sulphide films are frequently observed beneath the miscellaneous microbiological population which develops on such surfaces'.[98]

Recent observations were made on steel specimens which were exposed to sea water known to contain sulphate-reducing bacteria.[99] Rapid corrosion occurred and sulphate-reducing bacteria were found in the corrosion products which contained appreciable amounts of iron sulphide. Had there been no bacteria, it is inferred that the corrosion would have been less due to the accumulation of corrosion products and subsequent increase in the thickness of the ion diffusion path. But the bacteria appear to grow *beneath* the original coating of corrosion products and take the place of the excluded oxygen enabling the corrosion to continue.[100] Thus, by growing beneath the corrosion products, sulphate-reducing bacteria can cause rapid sulphide corrosion of metals even in oxidizing environments.

Sulphate reducing bacteria are of the genus Desulfovibrio and they create a corrosive environment by converting the comparatively harmless sulphates into the aggressive sulphides.[101] Their activity on the corrosion of iron could be represented as:[102]

Anodic solution of iron:
$8H_2O \rightleftharpoons 8H^+ + 8OH^-$
$4Fe + 8H^+ \rightleftharpoons F4e^{++} + 8H$
Cathodic depolarization:
$H_2SO_4 + 8H \rightleftharpoons H_2S + 4H_2O$
Corrosion products:
$Fe^{++} + H_2S \rightleftharpoons FeS + 2H^+$
$2Fe^{++} + 6OH^- \rightleftharpoons 3Fe(OH)_2$
The net overall reaction
for the process being:
$4Fe + H_2SO4 + 2H_2O \rightarrow 3Fe(OH)_2 + FeS$

Let us now consider each of the metals—iron, copper, silver, and lead—and discuss how they deteriorate in the sea-bed environment.

[97] *Ibid.*, 390. [98] *Ibid.*, 481. [99] *Ibid.*, 388. [100] *Ibid.*, 388.
[101] W. J. Copenhagen, 'Accelerated Corrosion of Ship's Bottom Plate', *Brit. Corr. J.*, 1, 9, 344.
[102] H. Uhlig, *op. cit.*, fn. 12, 469.

Iron

In the above general discussion iron was used several times as an example. There is no need, then, to repeat how concretions are formed on iron or how iron reacts in a reducing environment created by bacteria.

For iron which corrodes in an *oxidizing environment* Eriksen and Thegel give the following equation:[103]

$$Fe+2NaCL=2H_2O\rightarrow FeCl_2+2NaOH+H_2$$

ferrous chloride being formed rather than ferric chloride due to the lack of an abundant supply of oxygen. Also, because of the pressures encountered on the sea bed, water of crystallization is often bound to the ferrous chloride, 1, 2, 4, or 6 molecules of water being capable of binding with 1 molecule of ferrous chloride and having a formula of $FeCl_2 \cdot xH_2O$ where x frequently $=4$.[104] The ferrous chloride remains in solution within the corroding metal and when the object is brought out of the water, the real trouble begins. Eriksen and Thegel describe what happens when a gun is brought up from the sea-bed:

> When the gun is fished out, the external water pressure disappears and the solution of ferrous chloride begins to seep outwards; this produces the characteristic picture of the gun that "sweats". This sweating, depending upon the density of the iron, may obviously continue for many years, corresponding to the reverse process of penetration of salt water into the gun, which also takes many years. Gradually as the ferrous chloride solution (which has a salty taste) reaches the surface of the gun, it will force itself through any cover of paint possibly present, and the oxygen of air will begin to oxidize ferrous chloride to ferric chloride under the simultaneous liberation of iron which is oxydized to ferric oxide. This transformation follows the equation:
>
> $$6FeCl_2+3O\rightarrow 4FeCl_3+Fe_2O_3$$
>
> At the same time the oxygen of the air combined with the water of the ferrous chloride solution starts rusting of the iron. Since the rust formed ($2Fe_2O_3 \cdot xH_2O$ where x is most frequently $=3$) is porous, it cannot keep the air out and the rust layer will grow until a suitable preservation checks its growth.[105]

Conditions of the environment do not alone determine how well an iron object will survive. The composition of the iron—the amount of carbon, silicon, and phosphorous—is also important.

The graphite phase in cast iron can exert a controlling effect on the extent and distribution of corrosion after the first stages of attack. Usually

> The graphite is left mixed with the iron corrosion products in a fairly continuous and compact layer over the unattacked iron. To the extent that this layer is impervious to water, corrosion will cease or slow down. If the layer is porous, corrosion will be accelerated by galvanic action between the graphite and the iron.[106]

Thus, depending upon the nature of the layer, graphite can either protect against or accelerate corrosion.

> Low alloy content cast irons frequently demonstrate superior resistance to graphitic corrosion, evidently as a result of their more dense structure and the development of more compact and more protective graphite coatings.[107]

[103] E. Eriksen and S. Thegel, *Conservation of Iron Recovered from the Sea*, Copenhagen (1966), 90.
[104] *Ibid.*, 90–91. [105] *Ibid.*, 91 [106] H. Uhlig, *op. cit.*, fn. 12, 392. [107] *Ibid.*, 392.

The amount of silicon, manganese, and phosphorus will also affect the amount of corrosion. Silicon was added to cast iron to make it softer, less brittle, and more easily machinable. It is a common ingredient of old cast iron guns and cannon and was added to meet the requirements of withstanding the violent impact of the combustion of powder without shattering.[108] The addition of manganese and phosphorous, on the other hand, made the iron hard, brittle, and porous and was often added, for example, to cannon balls to give them added strength.[109] But if the iron is more porous, it is more easily penetrable to sea water under the sea, and to air once it is lifted, and is thus more liable to corrosion. Therefore, iron with a higher silicon content and a lower manganese and phosphorous content is more resistant to corrosion. This was discovered by Eriksen and Thegel in their analyses of iron recovered from the sea:

> The same was experienced in the four cannon balls: The so-called small ball with its modest proportions of manganese and phosphorous corroded moderately and slowly while the other balls corroded in the way that the surface peeled heavily and deep cracks developed as soon as they were taken out of the sea. The high proportion of phosphorous found in them affords the explanation.[110]

A final word should be made about concretions with regard to iron. These are two phenomena that recur frequently on marine archaeological sites. The first is the growth of a huge concreted mass of assorted objects. These masses are usually the result of very rapid corrosion of one or more large iron objects. The release of iron corrosion products into the water plus the increase of alkalinity causes a rapid precipitation of calcium carbonate and the growth of a massive concretion. Just such a concretion weighing nearly one ton was raised from the Kyrenia shipwreck and has yielded many types of materials from pottery to lead to copper, wood, and sandstone. In the centre of the concretion, there is evidence of a very large iron object which is now completely mineralized. The concretion has resulted from its corrosion.

The second phenomenon occurs when a concretion is broken open to reveal an empty shell where once there was an iron object. Presumably this occurs when the concretion formed is porous enough to allow for the easy diffusion of soluble iron corrosion products through the concretion into the surrounding water. These concreted 'moulds' reproduce the surface of the object which has disappeared and successful casts have even been taken in them. Apparently this is more usually a warm water phenomenon because the concretions formed in cooler waters are generally more compact and continuous and inhibition diffusion.

Copper and Copper Alloys

Copper and copper alloys recovered from a reducing marine environment are usually found to contain mainly the iridescent blue-black covellite (CuS) or chalcocite

[108] E. Eriksen and S. Thegel, *op. cit.*, fn. 103, 83. [109] *Ibid.*, 83. [110] *Ibid.*, 83.

(Cu_2S) and often have a very characteristic concretion which has the appearance of pitch that has been rolled in sand and broken shells.

Under *oxidizing conditions*, paratacamite ($CuCl_2 . 2Cu(OH)_2$) is the most common corrosion product but usually occurs with a mixture of cupric hydroxide and basic cupric carbonate. Cuprite (Cu_2O) often appears as a distinct layer adjoining the metal or as large reddish-purple crystals on the surface. It is interesting to note that gypsum ($CaSO_4 . 2H_2O$) is often found precipitated in the corrosion products.

The corrosion products described above apply to objects within the oxidizing sediments. If, however, the object is on top of or above the sediment a phenomenon peculiar to copper may occur in which the corrosion products are sloughed off leaving behind only a thin layer of paratacamite on the ever-decreasing surface of the object. The object has the appearance of having been badly eroded or worn down. If a copper object is subject to the movement of high velocity waters, and if the object releases copper ions into solution at a rate of 5 mg. of copper per sq. dm. of surface per 24 hours, [111] no corrosion products will form on the surface but will be carried away either in solution or in suspension. In addition, the toxicity of the corrosion products prevents any fouling organisms from settling on the surface. This fact has been put to good use against the problems of fouling:

> An interesting and traditional use of copper in contact with sea water is exemplified by the sheathing of wooden vessels for the dual purpose of protecting the wooden construction and eliminating the fouling of the bottom by marine growths. Copper in this application possesses adequate resistance to the corrosive attack of sea water, but at the same time there is slow solution of copper sufficient to prevent the growth of barnacles and similar marine organisms. The function of copper in this respect is recognised by the inclusion of copper compounds in marine fouling paints.[113]

Thus it is possible that copper objects retrieved from the sea that appear to have a very worn appearance need not have gained it merely as the result of physical scouring by moving water or shifting sand.

An excellent example of this effect will be noted in Plate 3 which shows two bronze handles with portions of the rim of a bowl found off the coast of Majorca. Apparently the bowl landed on its side and the bottom half was quickly buried in the sediment. The half above the sediment was subject to the moving waters and the corrosion products were washed away. At the same time, oxygen concentration cells were set up at the water-sediment interface and the rim quickly corroded until it broke into two parts. There is nothing left of the bowl itself and the buried half underwent normal corrosion processes under oxidizing conditions which resulted in the complete mineralization and formation of paratacamite. The 'eroded' portion still contains some metal covered by a very thin hard layer of corrosion products.

Bronzes usually show good resistance to sea water under oxidizing conditions, with alloys of higher tin content (8%) being definitely superior to those of lower tin content (5%).[113] Among the brasses, alloys containing 65 to 85% copper are more

[111] H. Uhlig, *op. cit.*, fn. 12, 401–2. [113] *Ibid.*, 64. [113] *Ibid.*, 393.

resistant while alloys of higher copper content corrode at higher rates and are more susceptible to dezincification. Dezincification, however, is often effectively suppressed by the presence of small amounts of arsenic, antimony, or phosphorous.[114]

Silver

Under *anaerobic conditions* silver objects can be completely converted to silver sulphide. Corrosion products are less voluminous than iron or copper and often have the appearance of pitch but differ from the copper concretions in that there is nothing having the appearance of embedded sediment particles or shell fragments. (Plate 4).

Silver survives well in an oxidizing environment presumably due to the formation of a protective coating of silver chloride. When alloyed with copper, the silver may not suffer at all. Examination of a concreted lump of coins found off Mauritius revealed no silver corrosion products at all—only those of the copper alloyed with the silver: paratacamite, cuprite, and covellite. Calcium sulphate was also present. It is interesting to note that the diver who found these coins is in the habit of watching for a series of short horizontal green streaks formed by copper corrosion products for these often signify the existence of either copper or silver coins.

Lead

Under *anaerobic conditions*, lead suffers badly from the action of sulphides and is easily converted to galena (PbS), becoming black and brittle.

Under *aerobic conditions*, lead is very resistant and often has a thin protective coating of either hydrocerussite ($2PbCO_3 . Pb(OH)_2$), cerrussite ($PbCO_3$) or phosgenite ($PbCO_3 . PbCl_2$) or a mixture of them. Concretions are not formed.

Examination of the lead from the Kyrenia shipwreck is a good lesson in the study of the marine environment. Lead which was still attached to organic material (i.e., the wood of the hull and caulking) was converted to lead sulphide presumably as a result of bacterial activity, and the lead which was found loose in the predominantly oxidizing sediment underneath the ship was barely affected having only a thin protective coating of lead carbonate. Yet another portion of the lead had a thin layer of lead carbonate on the surface with a thin layer of lead sulphide on top of that, which infers a change in the environment. Perhaps the carbonate was formed before the decay of the boat's organic matter progressed far enough to alter the environment.

Lead-tin alloys are highly resistant to attack by sea water but pewter objects often have a pitted surface. As tin is more electropositive than lead in sea water, this may result from the galvanic corrosion of the lead.

In this paper an attempt has been made to cover aspects of the marine environment which are applicable to problems encountered in marine archaeology, emphasising in the discussions of the specific inorganic materials those points which differ from the deterioration in a soil environment. Although there will be omissions which

[114] *Ibid.*, 393.

others may deem important, it is hoped that this material will be of some use to those interested in exploring possible conditions of the sea-bed environment and the causes of the deterioration of inorganic objects retrieved from it.

Acknowledgement

I should like to thank Mrs. Janet Lang of the British Museum Research Laboratory for providing x-ray diffraction reports on many metallic objects retrieved from the sea. These reports verified published sources listing marine corrosion products and gave me specific information on the objects which I was studying. I am grateful also to Miss Alexandra Tuckwell for the diagrams, figures, etc.

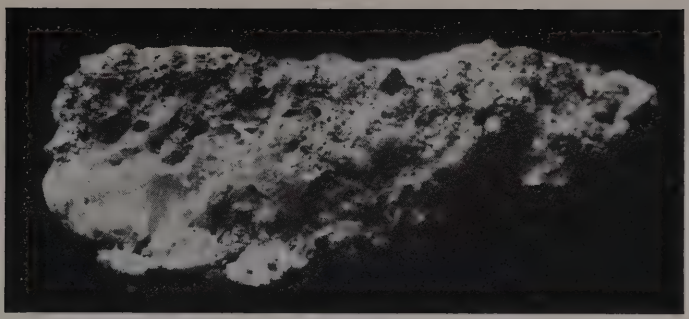


Plate 1 Macrophoto (x2.5) of chip off marble pedestal showing white marble crystals and darker repricipated calcium carbonate.

Plate 2 Macrophotograph (x2.5) of some fouling organisms on a pot found in English waters.

Plate 3 Top and side views of handles and portion of the rim of a bronze bowl.

Plate 4 Empty concretion of a silver coin from the wreck of a Spanish galleon in the Caribbean. (actual size).

Summaries of Undergraduate Reports 1972

The handaxes from Fordwich

The handaxes from the Third Terrace of the Great Stour near Fordwich in Kent were studied with a view to giving a more comprehensive picture of them than has hitherto been attempted. Nineteen handaxes were identified from the Bowes unprovenanced collection in the British Museum using Dr. Bowes' photograph album, recently discovered at Herne Bay, giving a total of 223 handaxes studied. Previous studies have emphasized the crudeness, irregularity, narrowness, and freshness of the implements and have suggested a Great Interglacial date for them. This study, using Bordes' methods of classification, shows that typologically more evolved pieces constitute a significant percentage of the total; recent geological information on the Great Stour suggests that the Third Terrace is periglacial in origin. These two factors suggest that a later date (Riss?) is likely for the Fordwich handaxes.

An assessment of the degree of wear suggests that the freshness of the implements has been exaggerated. Well over half of them are more or less heavily rolled.

A table to show the range of handaxe shapes, 7 figures to illustrate the main handaxe types, a map showing the distribution of the Great Stour river terraces in relation to the site and 14 tables with all the handaxe measurements are included.

A. M. Ashmore

The identification of bud-scales with reference to archaeological deposits

The aim of the report was to produce a collection of modern buds and bud-scales which might be used as comparative material for the identification of remains from archaeological sites. The structure of the entire buds, structure of individual bud scales, and the microscopic structure of each scale was studied. Thirteen tree species were studied and described.

Buds and bud-scales are likely to be present on archaeological sites wherever conditions of preservation are good. However, they have seldom been identified from archaeological deposits. The fact that they do occur on archaeological sites is illustrated by the recovery of thirteen buds from the Bronze Age Wilsford Shaft deposits. A study of these buds enabled some of them to be identified.

Bud and bud-scale analysis may produce useful environmental evidence. The results, when used in conjunction with other environmental studies, may help to produce a balanced picture of past environmental conditions.

C. A. Attwater

Some aspects of the Vinča culture

The Balkan-Anatolian theory of the origin of the Vinča Culture is adversely criticized from the standpoints of absolute and relative chronology, typology and ecology. Radiocarbon dates and vertical stratigraphy attest that Troy I and the Late Chalcolithic of W. Anatolia are irrelevant to the problem, whilst other supposedly mother cultures (the Middle Chalcolithic of W. Anatolia and the Black Burnished Ware groups of Mainland Greece) lack prototypes for many Early Vinča traits, especially figurines. Then follows a resumé of Starčevo and Vinča economic evidence. Next, a stratigraphical and typological definition of the Vinča-A stage at the type-site is attempted, based largely on Vassić's reports. The main conclusion drawn is that the material below 7.8 m.

represents a mixed Starčevo-Vinča occupation, denoted by the term 'Vinča-A'. Local prototypes for Vinča-A are examined in two stages:—

A) First Temperate Neolithic material associated with a limited number of Early Vinča forms;

B) 'Vinča-A' material.

Analysis of category B sites suggests a multi-regional derivation from local groups, with centres in the North Yugoslavian Banat, Bosnia, the Belgrade area and the Transylvanian Basin. This development is dated 4400–4300 radiocarbon years B.C. A final section reviews the importance of the Spondylus and obsidian trade in Early Vinča.

J. C. CHAPMAN

Some rich early Roman burials in south-east England

A study was made of a group of rich early Romano-British burials, distinguished by the inclusion of bronze vessels amongst the grave-goods. Twenty-six were located, their distribution falling into two main groups: one in northern Essex, the other in northern Kent. There were four others, the furthest afield being Welshpool.

A study of the grave-goods showed the pair of bronze vessels most frequently deposited was a patera and an ewer, often trefoil-mouthed. Some burials contained as many as four bronze vessels. Bronze or iron lamps were almost universally deposited, together with other items of glass and pottery, and occasionally iron.

The burials ranged in date from the middle of the first century to the end of the second century A.D. All were cremations, deposited in a variety of containers. About half were certainly beneath barrows and many were clearly in cemeteries.

There were many resemblances between these burials and the Welwyn-type burials of the late pre-Roman Iron Age. Furthermore, several could be shown to be close to large villa sites. It was concluded that these burials could pin-point the residences of the native aristocracy.

K. GOMER

The Pleistocene succession in the environs of Swanscombe, north Kent

The Pleistocene succession around Swanscombe has been studied as an isolated entity, in which the deposits have been allowed to speak for themselves, rather than being fitted into a more widespread chronological scheme of Pleistocene dating. Both present and past observations have been related to each other, assessed and analysed, and individual pits have been treated as interlinked units.

It can be said that the terms '100' or '50' for dating the deposits are a gross oversimplification of the chronology of the region. The Barnfield sequence, the most well-known in the area, is unique, for no other pit displays such a sequence of deposits of differing dates. The Barnfield Sequence is composite, with the top part probably belonging to Riss rather than the Great Interglacial, as probably do the nearby deposits at Craylands Lane and Galley Hill, lying on Crafm (chalk rubble and foreign matter), and the upper deposits at Rickson's pit which lie in a channel cut in the underlying lower gravel.

The main downcutting occurred with the onset of Riss cold phase 2 in the Ebbsfleet Valley, Riss interstadial 2/3 being in a previously unrecorded feature, unawareness of which has invalidated all previous attempts at dating the deposits exposed in the Ebbsfleet Valley. Thereafter, successively lower channel features in the Ebbsfleet Valley range in date from the end of Eemien to the end of Würm. The Baker's Hole industry, around whose date much controversy has centred, is apparently Würmian in date, belonging to the maximum of Würm I.

The report has attempted to demonstrate the advantages to be gained for dating purposes of studying the stratigraphies of a small area as an isolated entity. Several new and important observations have been made, and a number of interesting results obtained.

R. W. HARRISON

The Seed Remains from Wilsford Shaft, Wiltshire

2,793 seeds are described from the waterlogged infilling at the base of a Bronze Age Shaft (C^{14} 3330±90 B.P. (NPL 74) from material at bottom of Shaft, 100 feet deep). The Shaft, dug into Chalk and 6 feet in diameter, is only a mile from Stonehenge. Of the total number of seeds handled, 1.75% were not identified; of those identified 82.80% could be called weeds of arable land and cornfields, 11.59% weeds of grassland, 2.47% plants of hedgerow, marginal forest or scrub, 0.74% plants of variable habitats and 0.75% cultivated plants. This contrasts with the picture of dry, open grassland as the predominant habitat, based on the pollen and insect remains. It is likely that the seeds were deliberately put down the Shaft and therefore are not characteristic of the environment over a wide area but merely of a localised area near the Shaft entrance. This would indicate an area of arable land and perhaps a byre immediately near the site, and a wider landscape of dry open grassland, which was probably grazed, with scattered trees. The identification of the seeds is not meant to be definitive, so that the interpretation is somewhat speculative. No new light is shed from the seeds as to the purpose of the Shaft.

P. G. HAWKES

The end of Viroconium: The Roman City at Wroxeter, Salop

The report attempted to collect and review all the evidence concerning the end of Viroconium, the Roman city at Wroxeter, Salop. The bulk of this evidence lies in the excavations from 1859 to the present day, an old Welsh poem, an inscribed stone and an aerial photograph. At present, however, the evidence is too small, too controversial and too contradictory to formulate any safe conclusions. Nevertheless, a picture is at last beginning to emerge with the current excavations of Philip Barker. Here, on the site of the Baths Basilica he has found an important and impressive period of construction which he believes to have the hall marks of Roman public works, but translated into timber. It was tentatively suggested in the dissertation that this could have been part of the massive reorganisation by Count Theodosius after the 'barbarica conspiratio' of 367 A.D. Nevertheless, it is a fact that Wroxeter ended not with a whimper, but with a bang.

The report was part of a planned strategy of research, for Wroxeter cannot be studied in isolation. It is hoped to continue research into the other towns of Roman Britain, extracting where possible a coherent picture of C4th and C5th urban life.

E. C. HILL

British iron age linch pins in their continental context

British iron age linch pins may be divided into four morphological groups; a typological development may be traced in pins of Rod type. Continental analogies exist for each, but are vaguer for Rod and Crescentic types.

The distribution of the Crescentic type does not contradict the theory that they were introduced by the bearers of the Aylesford Swarling Culture. It cannot be shown that the Rod type was initially exclusive to Yorkshire. If it was introduced to Yorkshire with square-ditched enclosures, 'Yorkshire' bits etc., then there is a chronological and typological hiatus between this horizon and its supposed French counterpart which may be filled the late La Tène burial of Prunay (Les Commelles); an early start for the Arras series may be represented by Cowlam and Pexton Moor.

The problem of transitional metalwork still exists; our La Tène metalwork, including linch pins, appears already to have undergone strongly insular development.

The lack of La Tène pins with crescentic head in France may be due to the state of research, but there is nothing to suggest that the Evreux pin is not a response to British influence. La Tène pins of this type in Germany seem more akin to the Hallstatt examples than to British pins.

G. L. HUXLEY

A report on the Hoard from Stogursey, Somerset

The hoard from Wick Park, Stogursey, Somerset is that of a late bronze age founder, consisting mainly of scrap and broken pieces. Stogursey contains eleven South Welsh axes, more than twice as many as are found in comparable hoards in South Wales, where the main distribution of this type occurs. Also present are other decorated, plain and facetted axes, late palstaves, socketed gouges and knives, metal cakes and casting jets; types which are a regular component of the Llantwit-Stogursey tradition. In addition to these 'domestic' tools, there is a strong weapon element. Elliptic, ogival, lanceolate, fillet defined and barbed spearheads, swords and chapes, all present at Stogursey, are more characteristic of the Broadward and related weapon hoards. Contact with north and south-east England can be seen at Stogursey in the Yorkshire axe and carp's-tongue sword fragments. Stogursey is the only hoard which directly links the Llantwit-Stogursey, Broadward, Heathery Burn, and Carp's Tongue complexes to the same horizon, the Ewart Park Phase of the late Bronze Age in Britain.

R. McNeil

Romano-British pottery kiln sites

The report brings together the information concerning a total of twenty-eight Romano-British kiln sites in the counties of Norfolk and Suffolk. Site selection in relation to raw materials, transport and other settlements is considered; there is seen to be a preference for well-drained situations and a proximity to roads. A few sites appear to pre-date the Boudiccan revolt but the main expansion of the industry falls in the late first and early second centuries with a falling off in the number of sites in production in the late Roman period. Some of the sites appear to be industrial settlements with full-time pottery production whereas many others so far show no trace of any domestic occupation. This raises the question as to whether the industry was sometimes a seasonal occupation or whether there was movement between production sites by potters so that a larger market area could be served. A certain amount of geographical grouping of sites emerges from an analysis of the types of kiln construction, particularly in central Norfolk; this type of relation can only be clarified by a detailed study of the wares from each site and their distribution over the whole area.

J. Plouviez

Roman London, its roads and the Antonine itinerary

The origin of London as a Roman military site is reconsidered and its place in Claudian military tactics discussed. The development and expansion of the subsequent town through the first and second centuries is examined, with particular reference to the two street-grids, their relationship to approach roads, the Walbrook, and the three probable Thames bridge positions. Excavated structures and the distribution of the datable Samian pottery form the basis for the chronological development proposed.

Finally, the various routes of the 'Antonine Itinerary' which impinge upon London are re-examined in an attempt to explain the two and three-mile discrepancies which have been noted on all mileages approaching the capital. It is concluded that they result from the route mileages being measured from the city boundary (*pomerium*) and not from the centre or from the gates. By back-plotting the mileages from towns around London the probable extent of the city territory is demonstrated.

W. Rodwell

Housesteads Roman Fort—a re-assessment

Part I of the report is a summary of the history of research and excavation in the fort and civil settlement at Housesteads and it gives particular attention to the work done since 1959. Part II examines the problems of the Housesteads terraces and the conclusions of earlier researchers. The results of a small soil sampling programme taken from the terraces and from below the flagstone road outside the south-east corner of the fort are discussed. The terrace samples are much disturbed by worm activity and, because of the base-rich soil here, probably modern. All that can safely be deduced is that the area sampled has not been under cultivation in the recent past, i.e. from perhaps the early 19th century. The samples taken from below the flagstone

road are possibly of late 2nd century date. They produced less tree pollen than those from the terraces, showing that the area had probably long been cleared of forest. An extraordinary quantity of fern appeared—more than is to be expected by natural deposition. Possibly it was used for animal bedding or for drying out the road and thresholds before the flagstones were laid.

The third part consists of a discussion of the sources of the fort's water supply, and an analysis of features identified either by the study of aerial photographs or by field walking.

I. W. STUART

The relative chronology of Mersin: levels XXXIII–XVI

When excavated the site of Mersin was viewed in general terms as a Cilician outpost of the Mesopotamian sequence of Hassuna, Halaf and Ubaid. Recent work on the Anatolian plateau by survey and also excavation at Hacilar, Çatal Hüyük (East and West) and Can Hasan has made it fruitful to re-examine the archaeological sequence at Mersin.

Various interrelated fields were chosen for study. Firstly various aspects of the different features and levels needing updating are discussed, secondly external connections are re-examined, mainly in the sphere of pottery typology; finally a chronology is attempted which hopes to fuse together ideas of field-workers in the area into a meaningful compromise of a lot of confusing data. Particular problems which demand further study include the analysis of what seem to be local styles of painted pottery in Cilicia. For example from levels XXIV–XIX the importance of chevron and lattice motifs is individual to Mersin, detailed study of the earliest painted styles of contemporary sites would help place Mersin more specifically in the pattern of evolution/diffusion of painted pottery in the late Neolithic period.

Despite being overshadowed by recent discoveries on the Anatolian plateau, Mersin is worthy of further study; this attempt to bring it into line with current thought may help to make it important again for comparative studies.

D. E. WILLIAMS

The Severn Valley in Worcestershire—aerial photographs and pre-history

Aerial photographs from the Severn valley in Worcestershire show that this area was a focus of settlement as well as a trade route throughout the prehistoric period. The very earliest occupation along the river may have been during the Mesolithic at Gorse Hill and St. John's, Worcester, which have produced a concentration of flints. As yet aerial photography has failed to reveal sites characteristic of the Neolithic, such as cursus monuments or henges. However evidence that trade in stone axes was passing along the river terraces from at least three different regions during this period makes it possible that settlement sites may be found in future.

By the Bronze Age there is a definite concentration of finds along the river valley, especially between Bewdley and Worcester, as well as regular circles revealed from the air. Excavation supports the assumption that these are the ditches from around barrows.

Present knowledge suggests there is a change in settlement pattern during the pre-Roman Iron Age—a movement onto the heavier soils to areas chosen for their defensive position. This conclusion must remain tentative until further crop marks in the Severn valley are investigated.

J. WOODHOUSE

Book Reviews

BENSON, Elizabeth P., *The Mochica: A Culture of Peru.* (Library of the Art and Civilization of Indian America.) Thames and Hudson, 1972. 164 pp., 144 ills. £4.50.

The publishers emphasize that the volumes of this new series are intended for the general reader, and *The Mochica* must therefore be judged rather as a work of popularization than as a contribution to scholarship. By these criteria, the book is a success. The text is clear and readable, the photographs (in colour and in black and white) are well printed and well chosen, with a judicious mixture of well known and unfamiliar specimens. The captions to 5–21 and 5–22 are transposed, but there are few other signs of carelessness. The emphasis of the book is on the life and beliefs of the Mochica, as revealed by their artifacts and, above all, by the elaborately modelled and painted pottery with scenes taken from mythology and everyday life. There is no serious attempt to deal with purely archaeological problems of chronology and relationships with other cultures, nor to discuss such things as settlement pattern, water control and political structure on the basis of the available field evidence.

The book belongs in the 'art and life' category, and as such is not a bad example of its kind. Inevitably it relies heavily on the subjective interpretation of pictures, but the author is well aware of the pitfalls. She points out that the artists were selective in what they chose to portray. There are, for example, many war and ceremonial scenes but very few showing craftsmen at work; marine scenes and sea creatures outnumber agricultural scenes, even though the Mochica canal system demonstrates the importance of farming in the economy. The mythological subjects present all sorts of problems. Elizabeth Benson has done a useful job in isolating and defining certain figures and recurring combinations of themes, but I have doubts about many of her interpretations. The factual basis—and a rather slender one at that—is the scrappy information we have about Chimu (post-Mochica) religion as recorded at the time of the Spanish conquest. The rest is supposition and guesswork. Just one example must suffice. In the commentary on a vase painting with three mythological creatures, a jaguar, and two sacrificial victims, the author writes 'It is tempting to think that this . . . scene might represent an astronomical event—with the radiant god as the moon, the fanged god the sun, and the hawk creature Venus—that is celebrated by human sacrifice. The plant association with the radiant god may well have had to do with the tying in of the agricultural calendar with the moon cycle'. Tempting it may be to make unsupported guesses of that kind, but the temptation (and several others like it) should have been resisted. This kind of romantic wishful thinking detracts from what is otherwise a useful introduction to Mochica culture.

WARWICK BRAY

BUTZER, K. W. *Environment and Archeology.* Second Edition, London, Methuen, 1972. 688 pp., 95 figs., 23 tables, £8.00.

The first edition of this book (1964) has become the standard work on the subject. It covered the Pleistocene period and that part of the Holocene when man was a hunter-gatherer. It dealt with the origins and spread of agriculture, but not its later development. The new edition covers the same time range. As before, the first part of the book deals with the basic factors of world environments; then the author turns to different regions of the world, showing how evidence about early man and his environment can be obtained in many different ways in different geographical circumstances.

The new edition differs from the first in two main ways. Firstly, instead of a series of geographical surveys, the author has attempted an ecological synthesis of the environmental evidence

obtained from various sources. In some regions there is so little factual material available that ecological conclusions at best can be little more than hypotheses, but elsewhere we are able to see sequences of change which seem to fall into place in ecological terms. Butzer deplores the over-emphasis which is still given to dating techniques, geomorphological theory and regional stratigraphy and the failure to look at the total environment.

The second way in which this new edition differs from the first is in the great amount of new material which it incorporates. In some places this has been introduced as completely new chapters; elsewhere it is woven into the framework of the first edition. The continent of Africa, in particular, is now given much fuller treatment than was possible in 1964. This new material, quite apart from the ecological philosophy which underlies this edition, means that the first edition is now completely superseded.

G. W. DIMBLEBY

LINO ROSSI, *Trajan's Column and the Dacian Wars*, Aspects of Greek and Roman Life Series, Thames and Hudson, with 195 illustrations, 7 line drawings, 4 maps. £4.

This book, the first full commentary in English on the scenes on Trajan's Column and the most recent to appear in any language, is a considerable disappointment and the more so because there is a very real need for such a work, and the scale and price are exactly right. The main and most obvious criticism is that the illustrations—the raison d'etre after all for Rossi's study—are totally inadequate. Secondly, one can point to numerous small errors of fact (Roman cavalry *did* have saddles—*vide* Valkenburg, p. 85), slips (for 'short pants' read 'long trousers', p. 88), infelicities of English ('jugulate' for cut the throat, p. 64), spelling mistakes ('cask' for casque, p. 127), mistranslations (Anconis sublatis, p. 49, means 'putting cantilevers under it', not 'removing projecting elbows'), errors in interpretation (the ballistae, p. 164, are on platforms not in pits), specific examples of lack of knowledge (e.g. on the question of singulares Britannici—*vide* Birley in *Britain and the Roman Army*), and omissions (no mention of Hunts Pridianum). These are only a small sample of faults, minor in themselves, but large in number, which should never occur in a book of this type. Thirdly, one can criticise Rossi's whole approach. Richmond in his classic study of the column, *PBSR* XIII (1935), 1–40, probably over-reacted against the all too literal interpretation of continental commentators. With Rossi the pendulum swings right back—every dismounted rider represents a *cohors equitata* (the part-mounted infantry), while if a fort attacked by Dacians is defended by auxilliaries whose shields bear eight different designs, it is artistic shorthand for eight different forts under attack. In this connection Rossi's belief that shield designs would be well known to the public through illustrated handbooks 'regularly issued by the imperial authority', p. 100, is as bizarre as it is without foundation—for the *Notitia Dignitatum* is nothing of the kind. Even granted that specific units are represented, his attempts at identification lack conviction: in the same scene laurel wreaths on the shields of legionaries represent victory (we are to think of legion XXX Ulpia Victrix) and on those of auxillaries, the *torques* of units called *torquata*—since there would be a 'natural aversion' to using actual representations of these barbarian Celtic ornaments. This aversion was not shared by the soldiers shown on tombstones proudly bearing the miniature torques as military decorations.

All this could have been forgiven if *only* the pictures had been adequate, but as Dr. Rossi pointed his telephoto lens progressively higher these get steadily worse, until they finally fade into a grey blur. What is still required is a cheap and above all *clear* reproduction of the scenes of the column.

MARK HASSALL

ALEXANDER, John. *JUGOSLAVIA before the Roman conquest*. Thames & Hudson 1972. *Ancient People and Places*. 175 pp. £3.50.

Two things are clear, the first that this is a most welcome and competent survey, and the second that it has been marred at points by transposition of footnotes (e.g. the reference to pp. 42–47). When so much has been assembled so carefully it is difficult to allow that the author can be entirely to blame, and this he cannot be for the irritating corrigenda to all the Plate numbers,

nor for the system of reference itself which allows room for improvement. Some place-name errors are repeated (e.g. pp. 34, 36), and sites misplaced (e.g. Crvena Stijena on Map fig. 2), which is almost inevitable in eastern Europe. The radiocarbon evidence has not been assembled, which is always a useful devotional exercise in authors.

Having disposed of these points the rest is archaeology, and most useful too, especially with regard to the later periods and the Iron Age material which has specially concerned the author. One has to be aware that many interesting topics continue beyond the line which had to be drawn at the Romans. The palaeolithic and mesolithic are usefully marshalled, although reflecting the piecemeal state of present knowledge. With regard to the Neolithic it is regrettable that the subdivisions of Starčevo have been perpetuated as a chronologically valid system without criticism, nor is the First Temperate Neolithic in any way meaningfully related to the 41st parallel (p. 34), and certainly not south of it. The claim for wild grain species within Jugoslavia is quite ill-founded, certainly in the confident terms stated (pp. 27, 31), and such things once in print require a great deal of effort to exterminate.

The Rod Head figurines of the FTN are limbless (p. 35) because damaged, and the idea that they reflect wooden or stone prototypes is not really traceable to the references given but rather through e.g. Srejović in IPEK, 21. In any case its proponents should roll a few lumps of clay together, or try making coffee-bean eyes on stone.

The title of chapter III is confusing in that the classification of Pločnik, or Baden and other matter among bronze-using communities may mislead some people. (The same applies to the placing of Lepenski Vir in a 'Mesolithic Period 8000–6000 BC'). In fact we can see that the very uncertainty inherent in the terminology of a 'Copper Age' has its value, in that it gives us to think over the basis of our classifications, and in the abrupt transitions induced by its removal. It can be agreed that the development of metallurgy in the Balkans followed a very different course from that in Western Asia and the Aegean, but there is a great deal to be said nowadays against the idea (p. 54) that it was 'less sophisticated' and 'very slow'.

The simplification of the Jugoslav Iron Age terminology into an early Iron Age I (700–350 B.C.) and II (350–11 B.C.) is welcome and appropriate. The dividing line is as well chosen as any dividing line can be, not least because it corresponds relistically with the real structure of the adjacent Roumania material in a way which 'Hallstatt' and 'La Tene' do not. The topics which transcend the geographic limits of the book, such as the close relation with Roumania from Basarabi and Balta Verde on, hence with Troy VII B, and with Verghina in Greece, deserve consideration some time in this wider framework, just as much of the northwestern Jugoslav Mesolithic needs to be discussed in a north Italian context, or some of the Bosnian Iron Age pins (p. 105) linked to those in Albania. We would not have minded a condensed account of the main indications from those useful pins and fibulae of regional and chronological patterns within Jugoslavia, but if the author's modesty did not allow him to dwell on this he may have been right not to break up the flow of an account which we accept from him with gratitude.

JOHN NANDRIS

ALCOCK, Leslie, *Cadbury/Camelot; Excavations at Cadbury Castle 1966–70*, London, Thames and Hudson. 1972; 224 pp., 110 pls., 15 in colour, 36 figs. £4.75.

There are many things about this book, apart from the archaeology, which seem to strike just the right note. The dedication to the supervisors of the first year of excavation, one of the first things after the title page, may seem an unimportant point in a short review, but it sets the scene and plots the course of the book which is faithfully carried through to the end. This is a book about a dig and, as such, it spends a good amount of space explaining in simple, but never patronizing, terms what was done, why it was done, and how it was done.

Prof. Alcock has been very kind to his erstwhile opponents, so it is probably wrong to spend much time considering the disagreements which attended the digging of Cadbury. Every so often there come asides in the text which refer to the critics of 1968 and 1969 which are so gently phrased that it would be impossible to reconstruct from them the heat generated at the time. If the critics had had their way adequate funds for the final season might never have been gathered, and the results of the whole work would have been woefully incomplete. These happenings, together with developments in geophysical surveying, and Prof. Alcock's excellent picture of himself unpicking

a rampart after the workers had gone so that they should not be lead astray if he made a mess of it, were part of the digging of South Cadbury, and they have an equal share in his exposition.

It is a fundamental principle of this book that a subject should not be introduced unless it can be explained in completely comprehensible terms. This is excellent, though it does lead to one rather puzzling explanation. Alcock wishes to talk about the absolute date of the Neolithic occupation, and true to his rule he therefore has to explain, not only the ideas of radiocarbon dating, but also the present uncertainties of this method. He puts the problems at the door of radio-active disintegration and suggests that this random process has undergone "external checks (which) have now shown that the rate of decay has not been constant". I think some wires have got crossed here, for the usual explanation of C^{14} problems is the variation of carbon isotopes of the atmospheric carbon dioxide, or the differential uptake of carbon compounds by living organisms. This example, which is the only one which stood out in a fairly careful reading of the book, is a tribute to Alcock's determination not to shirk any of the many explanations which the reading public requires before it can understand fully the results of archaeological research.

The summary of present views on results from Cadbury which is presented period by period from Neolithic to Medieval gives a very good conspectus of archaeological problems in southern Britain, and sets the individual site into a satisfactory background. The illustrations throughout are clear, relevant to the text, and well described, though, with the best will in the world, it has evidently proved difficult to find views which would both give information, and yet convey the considerable distances involved at Cadbury.

As the "book of the dig" this sets a new high standard of honesty and information which will be very difficult to live up to, let alone surpass.

RICHARD REECE

SCHAEFFER, C. F. A. *Alasia I* (*Mission archeologique d'Alasia IV*) (Paris 1971) XII+573 pp., 347 figs., 37 pls., with 4 maps in pocket. Fr. 376.

Nearly 40 years have elapsed since Professor Schaeffer began his excavations at Enkomi and this volume marks the 20th season of work. In this sense it is a *Festschrift* in honour of Professor Schaeffer's expedition, originally a joint enterprise with the late Dr. Porphyrios Dikaios of the Cypris Department of Antiquities. Dr. Dikaios' three volumes appeared shortly before his death; this is the first giving definitive results of Professor Schaeffer's work.

A number of scholars have contributed papers: Dr. Aitken's magnetometer survey in 1958 produced anomalies but the soil made it somewhat ineffective, except for providing an outline of the road system. Dr. Catling writes on a bronze female statuette standing on an ingot and discusses the relations with the Enkomi ingot-god of the 12th century B.C. and the religious connections between the gods and the metal industry. Dr. Hadjijoannou suggests that the horned god found by Dr. Dikaios, is Apollo Kereatas, protector of herds, and discusses the connection between Apollo and Nergal. R. W. Hutchinson writes on 'Knots and streamers' as symbols of gods: and Dr. Karageorghis publishes some new examples of the 'Bull and protome painter' of Mycenean vases. Mr. Megaw discusses a decorated Byzantine glass bottle, formerly thought to be from Syria, but on recent evidence from Constantinople, Cyprus and Corinth, now to be attributed to Constantinople as a place of manufacture. Meriggi publishes some Hittite terracotta sealings from Arslan Tepe.

But the greater part of the volume is concerned with reports of Enkomi itself. Johnstone describes a rare tholos tomb belonging to Late Cypriot I under the later houses. Over 200 pp. are occupied by Courtois' detailed account of the sanctuary in which the bronze ingot-god was found, belonging to the 12th century B.C. The god was found in a small *cella* in the corner of the main courtyard together with a few pots. But the principal finds were in the courtyard with stone benches round the side, with bull's skulls and pottery which had fallen from them, together with terracotta animal figurines. In the centre were monolithic altars with associated hearths for sacrifices. As the site was abandoned after destruction by earthquake and flood, the objects were *in situ* and it is possible to visualize the layout of the Late Cypriot III sanctuary. Other sanctuaries in the town are similar, as is also Myrtou-Pigadhes excavated in 1950. The paper is fully illustrated with plans, sections and photographs; but as the position of sections is rarely marked on the plans,

and the items referred to in the text are not always shown, it is sometimes difficult to relate text to illustrations. This is also the case in the tholos tomb report.

The second important find is the founder's hoard from Well 212, already partly described in *Ugaritica VI*. It is here listed in full by J. Lagarce, who gives a brief comparison with other hoards and draws attention to the close relation with the Gelidonya wreck. The hoard is dated to the 12th century B.C. Bouzek discusses the swords from the hoard and the distribution of similar Naue II types in Europe. Hundt describes the conservation of the material.

Professor Schaeffer summarizes the results of the study of the sanctuaries and the position of the bronze statuettes found abandoned in several of them. He suggests that the site was destroyed by earthquake and flood which buried the buildings. Some statuettes were recovered and re-buried at a higher level, but there was no real re-occupation after the 11th century B.C. He also discusses the copper ingots and the metal industry and trade.

But perhaps the most interesting item is the complete map of the excavated town (in pocket) showing the walls and street plan. Professor Schaeffer describes this in the last chapter from which one obtains an impression of the main North and South street with cross streets at right angles, dividing the town into industrial religious and other quarters.

The book is lavishly illustrated on glossy paper throughout but the photos are sometimes of poor quality and one could wish that some of these had been replaced by one or two well selected pictures which would have brought the details out better. Nevertheless, the volume is of great importance for Cypriot archaeology and the Mycenean period in general.

JOAN DU PLAT TAYLOR

THOMAS, C., *Britain and Ireland in Early Christian Times A.D. 400–800*, London, Thames and Hudson: 1971. 144 pp. £1.75.

Largely rewritten and with a new set of illustrations this book is a re-issue of Professor Thomas' chapter in *The Dark Ages* published in 1965. It forms a companion to Professor Wilson's *The Vikings and their Origins*. For Thomas there are three characteristic features in the four centuries between the end of the Roman occupation of Britain and the first Viking raids; the migrations and settlements, the rise of Christianity, and the diversity of spoken and written languages. He presents a general picture with these three factors in mind. The Anglo-Saxon areas of Britain have been the subject of many archaeological studies but on the whole the north and west have received very little attention. This book is biased towards the north and west of Britain for which it is an exceedingly useful introduction filling a serious gap in the literature. The original *Dark Ages* chapter has been expanded to four: 'The End of Roman Britain'; 'Invasions and Colonists'; 'Christianity'; and 'Home and Hearth'. In the second chapter Thomas surveys the main migration and settlement of the Germanic peoples over the fifth and sixth centuries, Arthur and Badon, and the Picts during the sixth and seventh centuries. There are useful distribution maps of the place-name element *pit*—souterrains and Pictish symbols, with useful summaries of the evidence for emigration of people from Ireland to Scotland, to Man and to Wales. The presence of Irishmen in Cornwall is well attested by a group of memorial stones, inscribed in Irish ogam and Latin letters. The area covered by these coincides with a group of parishes with Irish and specifically Ultonian saints names and a number of sites have produced grass marked pottery resembling the 'souterrain' ware of Ulster, which is also found in Iona and the Hebrides. Thomas sees the pottery as the result of Irish settlers coming especially from Ulster. This view however, has been contested by Clark and Alcock.

It would have seemed advantageous to mention in more detail the 'small tools and ornaments' from Cornish sites which find their only known parallels in Ireland; for instance the iron bridle-bit cheek piece with silver from Gwithian. Thomas has written elsewhere that the Dumnonian rulers were not agreeable to the Irish invasion and that the "Giants' Hedge" which runs from Lerryn to Looe, can be seen as an attempt by a Dumnonian king at Castle Dore to fortify his royal estate against a hostile region in north Cornwall. Although Castle Dore is mentioned elsewhere in the book Thomas unfortunately does not pursue this interesting thesis here. In this chapter

the illustrations get very out of step with the text. It is also unsatisfactory that the illustrations of two stones inscribed to Irishmen do not record the provenance (Fig. 45 from Castell Duryran, now in Carmarthen Museum; Fig. 46 from Gulval, Cornwall).

The advance in the study of early Christianity in Britain and Ireland makes chapter three particularly interesting with its survey of fourth-century Christianity and the first monasteries. The archaeological contacts with the Mediterranean are considered, with distribution maps of imported pottery. It is unfortunate, however, that with so few dots on the maps, sites are not identified. The treatment of the Christian dead with a discussion of inscriptions and cemeteries is useful, though is no substitute for the chapter on the subject in Thomas' recent book *The Early Christian Archaeology of North Britain* (1971). The final chapter suffers from brevity and the lack of plans and the section on craftsmanship sits uncomfortably here.

The book, with good line drawings and nineteen colour illustrations, is well produced but a major criticism of the series is the awkward placing of illustrations, with captions not always near-by or even on the same page, and the lack of scales or dimensions. The bibliography is useful and there is an index.

LAURENCE KEEN

Proceedings of the Sixth Seminar for Arabian Studies London, (Seminar for Arabian Studies, 1973, Institute of Archaeology, London) 74 pp., 7 figs., £2.00.

This volume contains nine papers, or summaries of papers, delivered at the Seminar held in the Institute of Archaeology in London, September 1972. They deal with subjects as disparate as 'Harappan Trade in the Persian Gulf in the Third Millennium B.C.' by Dr. Elisabeth C. L. D. Caspers, and Professor Jacques Ryckman's 'Ritual Meals in the Ancient South Arabian Religion'.

Rather than attempt to summarize—or even comment upon—the individual papers in a limited review, it is probably better to note how valuable a contribution this small annual Seminar is making. It is rapidly becoming an important forum for those who are interested (as archaeologists, historians, economists, linguists, art historians) in the Arabian Peninsula and its neighbouring lands in the ancient and modern world. Its annual publication, neatly but cheaply produced by a photographic process, is good value at £2.00. Although it could be improved by more careful editing and proof-reading, its prompt appearance compensates for the few faults of this kind.

Obviously, interest in Arabia is growing rapidly. A large well-attended international Symposium on Arabia in Antiquity, sponsored by Harvard University in December 1972 indicates that a new meeting of minds and disciplines is taking place also in America. The new Saudi antiquities law, the recent exploratory work along the Arab-Persian Gulf in the Eastern Province, Oman and the Trucial States, are all manifestations of the new interest by the governments of the states of the Arabian peninsula. Credit must certainly go to Mr. Peter Parr and Mr. John Dayton who, in many ways, anticipated this growth of interest and have been diligently and intelligently providing a focus for such studies in Britain.

A. D. TUSHINGHAM

BOOKS RECEIVED

The following books have been received. The fact that they are listed here does not preclude their review in a later issue.

BASS, GEORGE F. *Ed.*	A history of seafaring based on underwater archaeology Thames & Hudson, 1972	£6.00
BOWEN, E. G.	Britain and the Western Seaways Thames & Hudson, 1972	£3.50
CARPENTER, RHYS	The sculpture of the Nike Temple parapet McGrath Publishing Co., Reprint 1971	$32.00
COLES, JOHN	Field archaeology in Britain Methuen, 1972	£3.50

Cook, R. M.	Greek painted pottery. 2nd ed. Methuen, 1972	£10.00
Crowfoot, J. W.	Early churches in Palestine McGrath Publishing Co., Reprint 1971	$36.00
Dickens, Guy	Hellenistic sculpture McGrath Publishing Co., Reprint 1971	$38.00
Fehring, Günter	Unterregenbuch Muller & Gräff, 1972	
Ferguson, John	The heritage of Hellenism Thames & Hudson, 1973	£2.25 cloth £1.25 paper
Harris, H. A.	Sport in Greece and Rome Thames & Hudson, 1972	£4.50
Howard, John A.	Aerial photo-ecology Faber & Faber, 1970	£7.00
Kidder, J. Edward	Early Buddhist Japan Thames & Hudson, 1972	£3.50
Kurtz, Donna C. & Boardman, John	Greek burial customs Thames & Hudson, 1971	£3.50
Masson, V. M. & Sariandi, V. I.	Central Asia. Turkmenia before the Achaemenids Thames & Hudson, 1972	£3.50
Maxwell Hyslop, K. R.	Western Asiatic jewellery, c.3000 B.C.–612 B.C. Methuen, 1970	£10.00
Newell, R. & Vroomans	Automatic artifact registration Oosterhout, Anthropological Publications, 1972	£1.90
Page, R. I.	An introduction to English runes Methuen, 1973	£4.65
Payne, Humfrey	Necrocorinthia McGrath Publishing Co., Reprint 1971	$52.00
Reichel-Dolmatoff, G.	San Augustin: a culture of Columbia Thames & Hudson, 1972	£4.50
Renfrew, Colin	The emergence of civilisation. The Cyclades and the Aegean, in the 3rd millennium B.C. Methuen, 1972	£15.00
Renfrew, Jane M.	Palaeoethnobotany Methuen, 1973	£6.50
Rothenberg, Benno	Timna: Valley of the Biblical copper mines Thames & Hudson, 1972	£6.00
Srejovic, Dragoslav	Europe's first monumental sculpture: new discoveries at Lepenski Vir Thames & Hudson, 1972	£6.00
Van Deman, E. B.	The building of the Roman aqueducts McGrath Publishing Co., Reprint 1973	$85.00
Wilkes, Bill St. John	Nautical archaeology David & Charles, 1971	£2.75

UNIVERSITY OF LONDON

INSTITUTE OF ARCHAEOLOGY

Twenty-ninth

ANNUAL REPORT

1 August 1971—31 July 1972

COMMITTEE OF MANAGEMENT

THE VICE-CHANCELLOR (Professor Sir Brian Windeyer)

THE CHAIRMAN OF CONVOCATION (Sir Charles Harris)

THE PRINCIPAL (Sir Douglas Logan)

The Director of the Institute (Professor W. F. Grimes)*

The Director of the Courtauld Institute of Art (or other representative) (Professor G. Zarnecki)

The Director of the Institute of Classical Studies (Professor E. W. Handley)

The Director of the Warburg Institute (Professor E. H. J. Gombrich)

The President of the Council for British Archaeology (or other representative) (Professor C. Thomas)

The President of the Prehistoric Society (or other representative) (Dr. J. D. Cowen)*

The President of the Society of Antiquaries (or other representative) (Sir Mortimer Wheeler)

Recognised or Appointed Teachers in cognate subjects, or Heads of Schools or Institutes in the University:—

Professor G. H. Bolsover	Professor R. A. Humphreys
Mr. J. G. Burton-Page	Professor H. S. Smith
Professor P. E. Corbett*	Professor W. Watson
Professor Eugénie Henderson	(*One vacancy*)

Two members of the non-professorial staff nominated by the non-professorial staff through the Academic Board:—

Dr. W. M. Bray	Dr. F. R. Hodson

The four Professorial Heads of Department of the Institute (ex officio):—

Professor G. W. Dimbleby*	Professor E. E. D. M. Oates
Professor J. D. Evans	Professor D. E. Strong

Five other persons:—

Dr. R. L. S. Bruce-Mitford	Lord Fletcher
Professor J. G. D. Clark	(*One vacancy*)
Mr. A. R. Dufty	

Lord Fletcher acted as Chairman throughout the session.

*Members of the Financial Sub-Committee

ADMINISTRATION

Director:	Professor W. F. Grimes, C.B.E., M.A., D.Litt., F.S.A., F.M.A., (*A.T.*)*
Secretary and Registrar:	E. Pyddoke, F.S.A.
Director's Assistant:	Mrs. M. Hunt
Senior Executive Officer:	Miss J. V. Brown
Executive Officer:	Miss M. P. McKenzie (until May, 1972) Miss M. E. A. Crabtree (from June, 1972)
Secretarial Assistants:	Miss C. F. Crickmore (from May, 1972) Miss L. Mullings (from September, 1971)

Staff Matters

The Director continued to serve as Chairman of the Royal Commission on Ancient Monuments in Wales and Monmouthshire and as a member of the Royal Commission on Historical Monuments (England) and the Ancient Monuments Boards for England and Wales. He continued as Chairman of the Field Studies Council, Council for British Archaeology Committees on Ancient Agriculture and Industrial Archaeology, the London Topographical Society, the Deserted Mediaeval Villages Research Group, the Nene Valley Research Committee, the Milton Keynes Research Committee and the Committee on Environmental Education within the Council of Environmental Conservation, of which he was a member. He served as a member of the Conference on the Training of Architects in Conservation, the Conservation Liaison Committee, the British Trust for Conservation Volunteers, and the National Trust. He continued to act as Honorary Treasurer of the Council for British Archaeology.

Professor J. D. Evans has been appointed Director of the Institute as from 1st October, 1973.

Professor Evans continued to serve on the Councils of the Royal Anthropological Institute and the British Institute of Archaeology at Ankara; on the Advisory Committee of the Horniman Museum and the Archaeology Committee of the Gulbenkian Foundation.

Professor Strong continued to act as Chairman of the Society for Libyan Studies and was elected President of the British Archaeological Association.

Dr. Waechter was awarded the Rivers Memorial Medal for 1972 by the Royal Anthropological Institute; he continued to act as Honorary Secretary to the Institute. Dr. Bray was elected to the Council of the Royal Anthropological Institute.

**A.T.* Appointed Teacher, *R.T.* Recognised Teacher of the University of London throughout.

Mr. Hassall was elected to the Councils of the Society for the Promotion of Roman Studies and the Royal Archaeological Institute, and continued to represent the Institute on the Chelmsford Excavation Committee. Mr. Reece represented the Institute on the Colchester Excavation Committee. He sat on the Councils of the Royal Numismatic Society and the Bristol and Gloucestershire Archaeological Society and on the Cirencester Excavation Committee.

Mr. Parr spent the year in Chicago as Associate Professor of Near Eastern Archaeology. During his absence his teaching was taken over by Dr. Kay Prag, Mr. Ian Blake and Mr. David Price-Williams.

Mr. Hodges was elected Honorary Treasurer of the International Institute for Conservation. Miss Elizabeth Pye was appointed as Special Lecturer in the Conservation Department, financed by a grant from the International Centre for the Study of the Preservation and Restoration of Cultural Properties in Rome.

Mr. E. Martinez was appointed Technician in the Photographic Department.

Mrs. M. P. McKenzie resigned from and Miss M. Crabtree, Miss C. F. Crickmore and Miss L. Mullings joined the administrative staff. Miss A. Lagden resigned from and Miss S. F. Oakes and Mrs. F. MacDonald joined the secretarial staff.

Miss A. Tuckwell resigned from and Dr. H. Martin joined the Library staff.

Public Lectures and Exhibitions

In May, Professor Oates delivered an Inaugural Lecture on 'The Legacy of Mesopotamia'. Professor J. N. Casal (French Archaeological Mission, Paris) gave the Special University Lectures in Archaeology. Professor Casal lectured on 'Characteristic Aspects of the Indus Civilisation. Its Evolution and Growth', 'Indus Civilisation and Baluchi Cultures' and 'Problems of Chronology for the Indus Valley and related Areas'.

Other lecturers during the session included Professor K. Erim (New York University) (in association with the British Institute of Archaeology at Ankara and the Anglo-Turkish Society); G. Michell (in association with the School of Oriental and African Studies); Norman Hammond (Cambridge); Dr. B. Rothenberg (Tel Aviv University); Professor A. D. Trendall (La Trôbe University) (in association with the Institute of Classical Studies); Dr. J. d'A Waechter; Miss Honor Frost (in association with the Palestine Exploration Fund and the Council for Nautical Archaeology) and B. K. Thapar (Archaeological Service of India).

Exhibitions included a display of drawings and photographs of the Chalukyan temples; illustrations of the Swanscombe excavation; a display of plans and drawings reconstructing Roman buildings; and the annual display of work produced by students in the Photographic Department.

The Institute continued to work in close co-operation with the Extra-Mural

Department in teaching for the courses leading to the University Extension Diploma, with several courses being held in the building and lecturers, both here and elsewhere, including past and present students of the Institute. The Director again acted as External Examiner.

Students

The total number of students registered during the session was 198; in addition 61 Inter-collegiate students attended courses. Of Institute students 2 were registered for Diplomas; 70 for Higher Degrees (10 part-time); 23 for M.A. and M.Sc. degrees; and 50 for B.A. and B.Sc. Hons degrees. 39 students were registered for the course in Archaeological Conservation (14 part-time) and 14 Occasional students attended lectures and used the facilities of the Institute.

Eighteen students were awarded the B.A. Hons degree in Archaeology, 2 in the First Class, 8 in the Upper Second and 8 in the Lower Second Class.

Of the Higher Degree students, 32 were registered for the Ph.D. degree full-time (one in the Faculty of Science) and 3 part-time. Twenty-seven were registered for the M.Phil. full-time and 7 part-time. Ph.D.s were awarded to Mrs. I. Azouri (Prehistoric Department) in September, Miss S. E. Ramsden (Roman Department) and C. Doumas, A. J. Ammerman and K. A. Wardle (Prehistoric Department) in February. Five students were awarded the M.A. degree in Archaeology in November.

Ten students qualified for the Institute's Diploma in Conservation (four with a Mark of Distinction).

Thirty countries were represented by 65 students registered at the Institute as follows: Aden 1, Australia 2, Bahrain 1, Canada 5, Cyprus 2, Czechoslovakia 1, Denmark 1, Egypt 1, Finland 1, Germany 2, Ghana 1, Greece 5, Holland 1, Hong Kong 1, Hungary 1, India 1, Israel 2, Italy 2, Iran 1, Iraq 2, Jordan 1, Korea 1, Lebanon 1, Libya 1, Malta 1, Mexico 1, Nigeria 1, South Africa 1, Switzerland 1, Turkey 1, U.S.A. 20, Yugoslavia 1.

Students' Union

During the session the officers of the Union were as follows:

President:	David Williams	Richard S. Kelly
Secretary:	Richard S. Kelly	Simon Esmonde-Cleary
Treasurer:	A. Morton	Sioned Alban-Jones

The Students' Union continues to develop its activities on both the academic and the social side.

The Presidents with other representatives attended Academic Board Meetings and other internal Committees of the Institute; they represented the Union on the University of London Student Representative Council, on the Central London Area Committee of the National Union of Students, and on the Area Liaison Group

(Birbeck College) for Central London Colleges. Richard Kelly when Secretary also acted as Secretary to the University of London Union Entertainments Committee. Simon Esmonde-Cleary and Sioned Alban-Jones played active parts in the organisation of the University Archaeological Society, which is based at the Institute.

A total of six General Meetings was held during the year, including the Annual General Meeting in March. Attendances averaged 30 Union members. No doubt the increased activity compared with 1970/71 was in part inspired by the Government's publication in November of the *Consultative Document on the Financing of Student Unions*. Although the Institute Union would not have been directly affected by the proposals set out in the *Document*, it nevertheless supported strongly both other London unions which would have been so affected, and also the National Union of Students campaign on a national level against the proposals. On December 8th, with the co-operation of the Director and majority of staff, there was a one day suspension of all lectures, with a peaceful picket at the Institute entrance. Union members also participated in the demonstration march to the Department of Education on the same day. Twelve per cent of the membership attended, a higher proportional figure than was achieved by any other London union.

On the social side the Freshers' Conference party and the usual termly parties were held with much success. Towards the end of the session the Union was allocated a newly-constructed room in the Institute basement, as a centre around which further facilities will be developed.

During the week of November 15th-19th, in conjunction with the 'Friends of the Earth' Society at University College, a waste-paper collection was organised, the product of which, given to charity, was subsequently sold for re-pulping. The point was made that the 2 cwt or so collected was the equivalent in raw materials of two large trees, amply demonstrating the ecological argument for the conservation and re-cycling of raw materials at this time.

Of Institute Union Societies, only two were active during this year. The Archaeological Society (which is also the University of London Archaeological Society) and the Music Society, both produced interesting and varied programmes. The Archaeological Underwater Research Group was in abeyance owing to lack of support.

Gordon Childe Prize and Bequest Fund

Gordon Childe prizes for 1971/72 were awarded to Miss A. M. Ashmore (Prehistory) and Miss Carol Attwater (Human Environment).

Awards from the Gordon Childe Bequest Fund were made to Mr. T. F. C. Blagg (Archaeology of the Roman Provinces), Dr. W. M. Bray (Prehistory), Mr. J. C. Chapman (Prehistory), Miss A. Claridge (Archaeology of the Roman Provinces),

Mr. I. C. Glover (Prehistory), Mr. R. N. L. B. Hubbard (Human Environment), Mr. M. H. Newcomer (Prehistory) and Mr. D. Price-Williams (Western Asiatic Archaeology).

Margary Fund

Ten students received awards to enable them to travel to Israel, France, Italy, Cyprus, Turkey and Portugal.

Roman Department Fund

The Roman Department prize for 1972 was awarded to I. W. Stuart.

TEACHING AND RESEARCH

Institute Field Course

The Easter Vacation training excavation was held at Bedfont, under the direction of Dr. J. A. Alexander. Instruction was given by Mr. Stewart, Mr. Price-Williams and Mr. Dorrell. The excavation, which was a rescue operation, was given financial support by the Department of the Environment.

The Summer Field Course was held in Chichester, under the direction of Professor Dimbleby and the Director. Dr. Cornwall, Professor Evans, Mr. Hassall, Dr. Hodson, Mr. Reece and Miss Sheldon participated.

RESEARCH SEMINARS

Research Seminar on Archaeology and related Subjects. A four-day meeting was held on *Prosimian Biology* from 14th to 17th April. Fifty papers were given by an international gathering of scholars. The papers offered to the Seminar were revised in the light of discussion and are now in press. They will be published under the editorship of Professor G. A. Doyle, Dr. R. D. Martin and Dr. A. Walker.

The Institute's thanks are due to Dr. R. D. Martin, University College, London, and Miss S. E. Johnson for help in organising the Seminar.

Post-graduate Research Seminars. From the second term of the session a seminar was instituted to take place every four weeks. Its purpose was to provide post-graduate students with a forum at which to present their research topics as work-in-progress. While the seminar was not closed to persons outside the Institute, it was hoped that the bringing together of staff, post-graduate, and final year students in an informal situation would help to foster a sense of community among the Institute's post-graduate students.

The seminar met with a good response, and attendances varied between 20 and 35 people. The meetings will be continued in the 1972/73 session, perhaps at fortnightly intervals. The following papers were presented:

12th January A. Ammerman: Methods of measuring the diffusion rate of cereal agriculture into Europe

9th February Dr. M. Walker: Settlement, economy and neolithic origins in south-east Spain

8th March A. Kossé: Chemical investigation of archaeological field systems

3rd May Miss E. A. F. Kendall: A method for analysis of function in architectural remains

31st May M. Tzedakis: Some aspects of the neolithic in West Crete

Dr. I. C. Glover and Dr. J. G. Nandris assumed responsibility for organising these seminars.

Seminar for Arabian Studies

The Committee of Professor R. B. Serjeant, Professor A. F. L. Beeston, Professor E. Ullendorff, Mr. P. J. Parr, Mr. T. C. Mitchell, and Mr. J. E. Dayton (Honorary Secretary) was confirmed in office for a further year, and Dr. J. C. Wilkinson and Dr. B. Doe appointed to it.

The proceedings of the 1971 seminar were printed and are available.

The Sixth Seminar was held at the Institute on the 27th and 28th September, 1972, when the following papers were read:

1. Miss E. Monroe (Oxford): H. St. John Philby's contribution to the history of pre-Islamic Arabia
2. Dr. G. Bibby (Aarhus): The Al-'Ubaid culture of Eastern Arabia
3. Professor A. F. L. Beeston (Oxford): New light on the Himyarite calendar.
4. Dr. E. C. L. During Caspers (Amsterdam): Harappan trade in the Arabian Gulf
5. Professor J. Ryckmans (Louvain): Ritual meals in the South Arabian religion
6. Dr. M. Ghul (Heidenheim): Inscriptions in cursive South Arabian script
7. Miss B. de Cardi (London): Field work in N. Oman and Ras Al-Khaiman, 1972
8. M. Morton (London): An expedition to Oman (Film)
9. J. E. Dayton (London): Roman sites in the N. Hejaz
10. Dr. M. A. Shaban (Exeter): Abdullah b. Qays
11. Dr. J. C. Wilkinson (Oxford): Arab-Persian relations in Sasanid Oman
12. A. Williamson (Oxford): The kingdom of Hurmuz and Gulf trade in the 14th and 15th centuries A.D.
13. Discussion (led by Professor Beeston): Lihyantine Inscription JS.71

In accordance with Seminar policy, publication of the proceedings will follow in due course.

THE DEPARTMENTS

The Director continued to advise on the ancient defences of London in the Barbican area of the City.

Publications:

'Lily Frances Chitty' in *Prehistoric Man in Wales and the West*, eds. F. Lynch and C. Burgess (Bath, Adams & Dart, 1972) pp. 1–3

HUMAN ENVIRONMENT

Professor:	G. W. Dimbleby, B.Sc., M.A., D.Phil. (Oxon), (*A.T.*)
Reader:	I. W. Cornwall, Ph.D. (*A.T.*)
Lecturer:	Miss J. M. Sheldon, B.Sc., (*R.T.*)
Chief Technician:	P. I. Porter
Junior Technician:	N. V. P. Syers
Honorary Assistants:	Mrs. M. Barton Mrs. H. Jones
Secretarial Assistant:	Miss S. F. Oakes

Higher Degree students in residence are listed below:

Ph.D.

A. Kosse (*Faculty of Arts*): Soil investigations of 'Celtic' fields in England and Wales (joint registration with Professor Evans)

J. P. N. Watson (*Faculty of Arts*): The analysis and interpretation of animal bones from archaeological sites

M.Phil.

P. Dorrell (*Faculty of Arts*): Geomorphology and settlements in S. Italy

M.Sc.

R. N. L. B. Hubbard (*Faculty of Science*)

J. C. Bayley, Miss (*Faculty of Science*)

J. Hollin achieved his Ph.D. at Princeton University as a result of his work on interglacial deposits, his research having been pursued from the Institute.

B.Sc. Hons.

This year saw the first finals in the new B.Sc. Course in Archaeology (Human Environment). Of the two students who successfully graduated (1 in the Upper Second, 1 in the Lower Second Class), Mrs. Carol Keepax (née Attwater) was awarded a Gordon Childe Prize for her consistently high standard of work throughout the year.

Dr. Cornwall and Professor Dimbleby again delivered a number of lectures to societies on aspects of archaeological science, and Professor Dimbleby was involved in various activities connected with the present-day ecological crisis. He was also invited to give the Dalrymple lectures at Glasgow University. His subjects were: 'Contributions of the Natural Sciences to Archaeology', and 'Contributions of Archaeology to the Natural Sciences'.

Dr. Cornwall undertook two soil investigations during the summer. The first was a large collection of samples from Mr. Alcock's excavations at South Cadbury Hill-fort. A report was submitted. The second related to volcanic ash and pumice deposits from Acrotiri (Santorini) which was submitted by Mr. James Money.

During the year Mr. Michael Walker (University College of Wales, Aberystwyth) and Dr. M. Kislev (formerly of Hebrew University, Jerusalem then working at Groningen with Dr. van Zeist) spent time in the Department to learn various laboratory techniques.

Specialist reports were completed on a number of sites, but much backlog remains and further intake of samples is being severely curtailed.

Publications:

By Professor Dimbleby:

'Medieval Pollen from Jordan', *Pollen et Spores* XIII (3) (1971), pp. 415–420 (with C. Vita-Finzi)

'A Bronze Age Barrow at Mount Pleasant, near Normanby, North Riding', *Yorkshire Archaeological Journal* (1972), pp. 33–38 (with E. W. Sockett)

Pollen Report in H. E. O'Neil, 'King's School Garden Excavation, Gloucester 1964: Finds from the Turf Rampart', *Trans. Bristol and Glos. Arch. Soc.* XC (1971), pp. 221–223

Pollen Report in F. Lynch, 'Report on the re-excavation of two Bronze Age Cairns in Anglesey: Bedd Branwen and Treiowerth', *Arch. Camb.* (1971) pp. 11–83

'The Impact of Early Man on his Environment' in *Population and Pollution* (Ed. P. R. Cox and J. Peel, Academic Press, London), pp. 7–15

Edited, with P. J. Ucko and R. Tringham, *Man, Settlement and Urbanism* (London, Duckworth, 1972). (Proceedings, Research Seminar in Archaeology and Related Subjects)

By Dr. Cornwall:

'Geology and Early Man in Central Mexico' (Henry Stopes Lceture, 1970), *Proc. Geol. Assoc.* 82 (3) (1971), pp. 379–392

PREHISTORIC ARCHAEOLOGY

Professor: J. D. Evans, M.A., Ph.D., F.S.A. (*A.T.*)

Lecturers: J. d'A. Waechter, Ph.D., F.S.A. (*R.T.*)
F. R. Hodson, M.A., Ph.D., F.S.A. (*R.T.*)
J. G. Nandris, B.A., Ph.D. (*R.T.*)
I. C. Glover, B.A. (*R.T.*)

Lecturer in Latin American Archaeology: W. M. Bray, M.A., Ph.D., F.S.A. (*R.T.*) (*Joint post with Institute of Latin American Studies*)

Special Lecturer: T. Sulimirski, Iur. D., Ph.D. (Lwow), Hon. F.S.A.

Secretarial Assistant: Miss D. Gaze

There were 51 students in the Department. Of these, 21 were studying for the B.A. and 29 for Higher Degrees. Eight students were awarded the B.A. degree, one with First Class Honours. One Full-Time Occasional student attended courses. Teaching was also provided for 18 intercollegiate students.

Higher Degree students in residence are listed below:

Ph.D.

J. M. Fairbank, Mrs. (*née* Willoughby): The Castelluccio Culture of Sicily

J. J. Keighley, Mrs. (*née* Marriott): A comparative study of the development of Neolithic pottery in the Balkans with special reference to the Vinča and Vesselinovo cultures

E. A. F. Kendall, Miss: (Field of proposed research) Inca architecture

A. D. Kossé: Soil investigations of 'Celtic' fields in England and Wales (joint registration with Professor Dimbleby)

K. M. Kossé, Mrs. (*née* Krudy): (Field of proposed research) Central European Neolithic

M. H. Newcomer: An analysis of a series of burins from Ksar Akil, Lebanon

Y. G. Tzedakis: The Neolithic and Early Minoan Periods in Western Crete

M.Phil.

S. M. Frankenstein, Miss: (Field of proposed research) The Iron Age in Iberia

F. M. A. Healey, Miss: (Field of proposed research) Synthesis and filling-out of available evidence for the East Anglian Neolithic and its British and continental affinities

A. Watson, Mrs. (*née* Turner): (Field of proposed research) The British Lower Palaeolithic

M.A.

M. C. Anderson, Miss; J. Langdon, Mrs.; P. J. P. McGeorge, Miss; E. Risopoulou, Miss; L. H. Schaaf, Miss.

During the session the Ph.D. degree was awarded to the following students: Mrs. I. Azoury, A. J. Ammerman, C. Doumas and K. A. Wardle. Of the eight students who successfully took the B.A. Hons. (Prehistory and Human Environment) in June, 1 was placed in the First Class, 5 in the upper Second and 2 in the Lower Second Class.

Professor Evans attended the International Congress of Prehistoric and Protohistoric Sciences in Belgrade in September and spent the following six weeks in Greece visiting museums and sites and working on the finds from the Knossos excavations. He attended the Sheffield Research Seminar on the 'Explanation of Culture Change' and presented a paper. In May he paid a two week visit to Romania under the auspices of the British Council and in July and August directed excavations in the Iron Age settlement of Segovia, Campo Maior, Portugal. He again acted as External Examiner in Archaeology for Sheffield University.

Dr. Waechter again directed excavations at Swanscombe from June.

Dr. Hodson acted as Executive Editor to *World Archaeology* and as External Examiner in Archaeology at the Queen's University, Belfast.

Dr. Bray continued on the Editorial Board of *World Archaeology*. He also presented a paper at the Sheffield Research Seminar on the 'Explanation of Culture Change'.

Dr. Nandris visited museums and sites in Romania in August and September, with the support of the Hayter Fund. He attended the Belgrade Congress in September and presented a paper there on 'The Early Neothermal period in South-East Europe'. He also gave a lecture on 'The Danube Gorges' for the Extra-Mural Department.

Mr. Glover studied collections of prehistoric Indonesian artifacts in various Dutch museums in August and September. In the Easter Vacation he worked on the recording of palaeolithic cave art at Hornos de La Peña, Spain, with a University College expedition led by Dr. P. Ucko. He continued as a member of the Editorial Board of *World Archaeology*.

Mrs. Rosaly Evine continued as Research Assistant in computing to Dr. Hodson, financed by a grant from the Leverhulme Foundation.

Mr. Newcomer continued his research work in the Department with the aid of a grant from the Gordon Childe Fund, and gave a course of lectures on palaeolithic technology and typology.

Publications:

By Professor Evans:

'Neolithic Knossos: the Growth of a Settlement' *Proc. Prehistoric Soc.* XXXVIII (1971) pp. 95–117

By Dr. Waechter:

'Swanscombe 1971', *Proc. Anthropological Inst. of Gt. Brit. and Ireland*, 1971 (1972) pp. 73–78

By Dr. Hodson:

Mathematics in the Archaeological and Historical Sciences. Edited with D. C. Kendall and P. Tautu for the Royal Society and the Romanian Academy (Proceedings of the Anglo-Romanian Conference, Mamaia 1970) Edinburgh University Press. 565 pp.

'Numerical typology and prehistoric archaeology'. Paper in the above Proceedings, pp. 30–45

By Dr. Bray:

'Ancient American Metalsmiths', *Proc. Anthropological Inst. of Gt. Brit. and Ireland*, 1971 (1972) pp. 25–43

'Land-use, settlement pattern and politics in prehispanic Middle America: a review' in P. J. Ucko, R. Tringham and G. W. Dimbleby (eds.) *Man, Settlement and Urbanism* (Duckworth, London 1972) pp. 909–926

'Thermoluminescent dating of Colombian pottery in the Yotoco style' (with E. H. Sampson and S. J. Fleming). *Archaeometry*, 14, IX (1972) pp. 119–126

Various reviews

By Dr. Nandris:

Some 15 book reviews.

By Mr. Glover:

'Settlements and mobility among the hunter-gatherers of South-East Asia' in P. J. Ucko, R. Tringham and G. W. Dimbleby (eds.) *Man, Settlement and Urbanism* (Duckworth, London 1972) pp. 157–164

By Mr. Newcomer:

'Some quantitative experiments in handaxe manufacture'. *World Archaeology*, 3, i (1971) pp. 85–94

'Un nouveau type de burin à Ksar Akil (Liban). *Bulletin de la Société Prehistorique Francaise.* Tome 68 (1971) pp. 267–272

ARCHAEOLOGY OF THE ROMAN PROVINCES

Professor:	D. E. Strong, M.A., D.Phil., F.S.A. (*A.T.*)
Lecturers:	M. W. C. Hassall, M.A., F.S.A. (*R.T.*) R. M. Reece, B.Sc., F.S.A. (*R.T.*)
Executive Officer:	Miss S. E. Johnson

There were 40 students in the Department, of whom 13 were registered for the B.A. degree, 8 for the M.A., and 19 for other Higher Degrees (6 part-time). Twenty-five intercollegiate students attended the course on Roman Britain given by Mr. Hassall and Mr. Reece.

Higher Degree students in residence are listed below:

Ph.D.

J. P. Alcock (Miss) (*part-time*): Classical cults in Roman Britain
A. Bonanno (Dr.): Portraiture in Roman historical reliefs
A. P. Detsicas (*part-time*): Romano-British settlement in the Medway valley
R. Goodburn: A systematic survey of the development and history of the Roman villa in Britain
S. E. Ramsden (Miss): Roman mosaics in Greece: the mainland and the Ionian Islands
M. Roxan (Mrs.): The Auxilia of the Roman Army
J. Sampson (Mrs.): Hellenistic and Roman landscape reliefs

M.Phil.

T. F. C. Blagg: Roman architectural ornament in Britain
R. L. Bradley: N.E. England in the Late Roman and sub-Roman periods
H. Chapman: Itineraries and posting stations
A. J. Claridge (Miss): (*Field of proposed research*) Technique of Roman sculpture
B. J. H. Clauson: Development of Romano-British Fora
S. K. Digby (*part-time*): The coin reform of Aurelian and its effect on Roman Britain
J. H. Greenaway (Mrs.) (*part-time*): Roman settlement in the area of the Atrebates
M. I. Martin (Mrs.): Roman Spain
D. C. Michaelides: (*Field of proposed research*) Opus sectile
E. J. Sanford (Miss) (*part-time*): Trade and transport in Roman Britain
H. L. Sheldon (*part-time*): The Roman pottery industry in the counties bordering London.
M. A. Wardle (Mrs.): (*Field of proposed research*) Roman musical instruments

M.A.

D. D. Aldridge; D. D. Andrews; J. Dixon, Miss; E. W. B. Fentress, Mrs.; J. M. Holmes, Miss; M. L. Kelsey, Miss; L. A. Ross, Miss; N. H. H. Sitwell.

Miss Ramsden presented her thesis in November and was awarded a doctorate. Two students registered for the M.Phil. had their registrations cancelled. M.A. degrees were awarded to Miss H. M. Carver, Miss C. Dominice and D. Michaelides. Of the 4 third-year first-degree students who successfully took their B.A. Hons. examination in June, one was placed in the first class, 2 in the Upper Second and 1 in the Lower Second.

The series of seminars on Roman Craftsmen and their Techniques was again held, and the series on Roman Pottery was expanded to include a number of lectures by guest speakers. On 10th and 11th March a seminar was held on the Reconstruction of Roman Buildings. Fifteen papers were given and the meeting was attended by about 120 people from all over the country. An exhibition in connection with this seminar was mounted in the front hall.

The Professor gave a number of public lectures in London and elsewhere. He visited Libya on behalf of the Society of Libyan Studies in the summer, where he took part in the excavations at Benghazi and studied the sculpture at Cyrene. He continued to serve on the Board of Examiners in Classics. In the summer he spent three weeks studying Roman Art in Southern France and Italy.

Mr. Hassall continued to serve on the Boards of Examiners in History, Classics and Education. He gave lectures to archaeological and classical societies at Queen Mary College, and Manchester and Nottingham Universities, and in the series on 'Advances in Asiatic Archaeology' organized by the London Extra-Mural Department. He continued work on the inscriptions of Roman Britain and the inscriptions from Knidos. He spent two weeks at Knidos and visited Roman sites in Rumania during the Summer.

Mr. Reece continued the work of excavation and recording on the early medieval monastic site on Iona. He also continued excavating an early post-Roman and medieval site at Ewen in Gloucestershire.

Publications:

By Mr. Hassall:

The Romans, in the series *The Young Archaeologist* (Rupert Hart Davis, 1971), 112 pp., plates, line blocks

'Roman urbanization in western Europe', in P. J. Ucko, R. Tringham and G. W. Dimbleby (eds.) *Man, Settlement and Urbanism*, (Duckworth, London, 1972) pp. 857–861

'Roman Britain in 1970 II. Inscriptions' (with R. P. Wright), *Britannia* 2 (1971) pp. 289–304

'The non-random spacing of Romano-British walled towns' (with Ian Hodder), *Man* 6, no. 3 (1971), pp. 391–407

By Mr. Reece:

'Roman coinage in northern Italy', *Numismatic Chronicle* X (1971), pp. 167–180

'Cirencester Grammar School 1960–1' *Trans. Bristol and Glos. Arch. Soc.* 1970, pp. 11–14

'Two "Lost" mosaics at Cirencester', *ibid* pp. 175–176

'Further coins from Chedworth Villa', *ibid* pp. 176–177

Coin report in H. S. Gracie 'Frocester Court Roman Villa', *ibid* pp. 66–73

WESTERN ASIATIC DEPARTMENT

Professor: E E. D. M. Oates, M.A., F.S.A. (*A.T.*)

Lecturer in Archaeology of the Levant: P. J. Parr, M.A., F.S.A. (*R.T.*)

Lecturer in Mesopotamian Archaeology: Miss Barbara Parker, O.B.E., F.S.A. (*R.T.*)

Lecturer in Anatolian Archaeology: J. Mellaart, B.A., F.S.A. (*R.T.*)

Seminar in Metallurgy and Metal Typology: Mrs. K. R. Maxwell-Hyslop, F.S.A. (*R.T. Retd.*)

Secretarial Assistant: Mrs. P. Wyatt

The number of full-time students in the Department was 33. Ten students were reading for B.A. degrees, 4 specialising in Mesopotamia, 2 in Anatolia and 4 in the Levant. There were 2 students reading for the Levant Diploma. Four students, 2 in Mesopotamian archaeology and 2 in the Levant took their B.A. examinations in June.

Students registered for higher degrees were as follows:

Mesopotamia

M.Phil.

M. E. Stout, Miss: Warfare in Mesopotamia
D. S. Noble (*part-time*): The Development of Transport in Ancient Mesopotamia
J. E. Curtis (*part-time*): Assyrian Metal Work
H. A. Hawkes: Egyptian influence on Mesopotamian art
I. R. Schwab, Miss (*part-time*): Interrelations between Syrian and Mesopotamian Cylinder Seals
S. Shahin, Miss: The Development of Iranian Cylinder Seals
J. E. Dayton: Ancient Glazes in Western Asia

M.A.

J. Koyacs, Dr.

The Levant

Ph.D.

S. W. Helms: Urban fortifications in Palestine during the Third Millennium B.C.

M. Saghieh, Miss: Byblos in the Third Millennium B.C.

D. Price-Williams: Application of statistical methods to some problems of the Middle Bronze Age in Palestine

M.Phil.

D. C. Elliott, Miss: The Ghassulian Culture in Palestine

A. Harif: Palestinian Archaeology

M. Oakshott, Miss: Bronze Age Pottery in Palestine

M.A.

J. N. Berkers, M. P. Bidmead, J. R. L. Duckworth, Rev.

Anatolia

Ph.D.

O. Bilgi: Development and distribution of anthropomorphic figurines in Anatolia from the Neolithic to the end of the Early Bronze Age

J. H. Pullar, Miss: The Neolithic in the Zagros Mountains

J. Spencer, Mrs.: East Anatolian Early Bronze Age

M.Phil.

P. Santos de Jesus: Origins of Anatolian Metallurgy

Mr. Bilgi submitted his thesis during the session and was awarded a doctorate. Miss V. van Rijn was successful in the M.A. examination.

Professor Oates attended the Rencontre Assyriologique Internationale in Leiden in July and contributed two papers.

Publications:

By Professor Oates:

'The development of Assyrian towns and cities' in P. J. Ucko, R. Tringham and G. W. Dimbleby (eds.) *Man, Settlement and Urbanism* (1972) pp. 799–804

By Mr. Parr:

'Preliminary Survey in N.W. Arabia, 1968 Part II' (with G. L. Harding and J. E. Dayton). *Bull. Inst. Arch.* 10 (1970) pp. 23–62

'Settlement patterns and urban planning in the ancient Levant; the nature of the evidence' in P. J. Ucko, R. Tringham, and G. W. Dimbleby (eds.) *Man, Settlement and Urbanism* (1972) pp. 805–810

By Mr. Mellaart:

'Anatolian Neolithic Settlement Patterns' in P. J. Ucko, R. Tringham and G. W. Dimbleby (eds.) *Man, Settlement and Urbanism* (1972) pp. 297–284

EASTERN EUROPEAN MEDIEVAL ARCHAEOLOGY

Lecturer: D. Sturdy, M.A., B.Litt. (*R.T.*) (joint post with the School of Slavonic and East European Studies)

Mr. Sturdy continued research into the early phases of medieval town history, gave lecture courses at both the Institute and the School of Slavonic and East European Studies and concluded his excavations in Levens Park, Westmorland, where an early bronze-age ring-cairn proved to be overlaid and surrounded by dark-age occupation and field systems. He also interested himself in the preservation of medieval houses in Oxford. He was awarded a grant from the Leverhulme Trust for research into medieval parks.

Publications:

'Correlation of evidence of medieval urban communities' in P. J. Ucko, R. Tringham and G. W. Dimbleby (eds.) *Man, Settlement and Urbanism* (Duckworth, London, 1972) pp. 863–866

'Das Völkewanderungszeitliche Gräberfeld von Környe' By A. Salaman and I. Erdelyi, a review in *Man* 7, III (1972) pp. 492

'Medieval Field Systems in South Westmorland' in *Northern Archaeology* (1972)

How to pull a town down: A handbook for local councils

DRAWING AND SURVEYING

Lecturer: H. M. Stewart, B.A. (*R.T.*)

The number of students attending the course was 42 (15 First Degree, 11 Higher Degree, 1 Diploma, 10 Conservation, 5 Occasional).

Practical instruction in Surveying was continued in the Institute's Field course held during the Easter vacation at Bedfont near London Airport.

A further course in Archaeological Surveying was given in the Extra-Mural Department.

The help is gratefully acknowledged of Mr. E. H. Wickens of the Department of Photogrammetry and Surveying, University College London, for his annual lectures on photogrammetric plotting machinery.

Publications:

'A Crossword Hymn to Mut', *J. Egyptian Archaeology* 57 (1971), pp. 87–104

PHOTOGRAPHY

Head of Department:	Mrs. V. M. Conlon, I.B.P.I.
Lecturer:	P. G. Dorrell, B.Sc.
Technician:	E. Martinez

Forty-six students attended courses, including B.A., B.Sc., M.A., M.Sc. and Diploma students.

With the increase in students during the last few years changes have been made in the Department, and Mr. Peter Dorrell was appointed Lecturer and Mr. Edwardo Martinez Technician.

Photographic work for student research and dissertations increased the use made of the Department's facilities especially in the vacations. Although the students have been trained, the help of teaching staff is needed.

Once more kind permission was granted by the Guildhall, Natural History and Victoria and Albert Museums for students to practice photography. For excavation experience Messrs Harvey Sheldon and Peter Marsden permitted students to work on their sites at London Bridge and at Billingsgate respectively. Mr. Dorrell gave instruction in practical photography throughout the Easter field-course.

The Photographic Exhibition was held in June. Many specialised subjects were displayed, such as infra-red, ultra-violet in colour, and microscope studies of minute details.

Mr. Dearnley of Harrow Technical College kindly acted as external examiner for the theory examination.

Mr. Geoffrey Denford accompanied Professor Evans on his excavation at Segovia (near Campo Maior), Portugal as photographer.

CONSERVATION

Senior Lecturer-in-charge:	Miss I. Gedye, B.A., F.I.I.C. (*R.T.*)
Senior Lecturer:	H. W. M. Hodges, F.I.I.C. (*R.T.*)
Lecturers:	Miss P. Pratt
	Miss E. Pye, M.A.
Honorary Assistant:	Miss A. Plowden, F.I.I.C.
Secretarial Assistant:	Miss A. Lagden

Forty students followed the Conservation Course, 12 in their final year, 13 in their second year, 14 in their first year and one on block release for one year from Hong Kong, taking the Museum's Association Certificate in Conservation. Sixteen students were on part-time release from the British Museum, Horniman Museum, London Museum, Maritime Museum and Department of the Environment.

The Department's thanks are again due to Dr. A. E. Werner, Keeper of the Research Laboratory of the British Museum, both for acting as External Examiner and for help in many other ways; to Mr. Baynes-Cope of the same Department for instructing the students in the technology, decay and conservation of paper; and to the staff of the workshop of the Research Laboratory for instruction in specialist techniques in reshaping and mounting metallic antiquities. The help is acknowledged of the British Museum, the Horniman Museum, Department of the Environment and the Oxford City and County Museum in taking students during the Christmas, Easter and Summer vacations and for more prolonged periods during their third year.

In conjunction with the British Museum the Department instituted an annual seminar to cater for visiting overseas conservators requiring advanced training in conservation. The first seminar was held in April and May and consisted of two weeks of general lectures, mainly at the Institute, followed by four weeks of practical work at the British Museum on a topic selected from the following: conservation of metals; conservation of ceramics and stone; conservation of organic and ethnographical materials; making of reproductions by moulding and casting. It is hoped that further topics will be added in the future.

D. Akehurst, J. Bateman, Miss H. Eichner-Larsen (Mrs. Wielandt), Miss F. Halahan, Miss J. King, N. Nasser, E. Paterson, R. Salanson, Mrs. S. Turner, J. Spriggs and A. Shishtawi were awarded the Diploma in Conservation, D. Akehurst, F. Halahan, J. King and S. Turner passing with distinction. Mr. C. P. Ng passed the examination for the Museums Association Certificate in Conservation.

Miss Gedye and Mr. Hodges gave a series of lectures on 'Conservation in the field and the examination and treatment of metal artifacts', for the Cours de Perfectionnement, held at the Institut Royal du Patrimoine Artistique in Bruxelles. They also lectured on the conservation and examination of pottery for extra mural students. Mr. Hodges visited the Middle East Technical University in Ankara to lecture and advise on matters of conservation.

Miss Pratt took third year students to assist her in the following projects: the transfer of two Tudor wall paintings for the Buckinghamshire County Museum, Aylesbury; the transfer of a sixteenth century wall painting at Thame, for the Oxford City and County Museum; and the transfer of a medieval wall painting from a church in Frinsbury, Kent.

Miss Pratt also advised on the treatment of a Tudor wall painting at Rhydarwen, Carmarthen at the suggestion of the Royal Commission of Ancient Monuments in Wales. She spent two months in the summer working to conserve material from the site of Asvan, Turkey, and revisited the site of Anamur to look at the results of the treatment and tests she had carried out in 1971 on wall paintings and mosaics. These proved to have had satisfactory results. She also spent ten days at the Ankara Museum looking into conservation problems.

Miss Pye ran a weekend course for Leicester University Extra-Mural Department on the first-aid treatment of small finds. She helped Miss Pratt with the transfer of the Thame wall-painting. As part of her duties in overseeing foreign students for the International Centre for Conservation she was involved in the organization of a Travelling Summer School for Restorationists from the United States of America and she accompanied the school when it was in England. On behalf of the Society for Libyan Studies and the Department of Antiquities, Libya, she spent five weeks in Benghazi working on Roman wall-plaster from the site at Sidi Khrebish. She also spent five days in Rome visiting the International Centre for Conservation.

Vacation work was carried out by students in Iran, Greece, Turkey, Italy, Sicily, Israel and England (London, Southampton, Saffron Walden, Dragonby, Lincoln).

LIBRARY

Librarian:	Miss G. Talbot, M.A., A.L.A.
Assistant Librarian:	Miss H. M. Bell, B.A.
Senior Library Assistant:	Miss A. Tuckwell, M.A. (until July, 1972)
Library Assistant:	Dr. H. Martin, B.A., Ph.D. (from July, 1972)
Collections Clerk:	Miss J. Philips, B.A.
Secretarial Assistant:	Mrs. F. McDonald

The shelving in room 103 (which is now fully incorporated in the library) was completed just in time for the annual check. It thus became possible to move in some of the periodicals from the anteroom, making room for a general rearrangement which has eased for the time being the pressure on space.

With the increase of funds allocated for the purchase of books, 200 more than in previous years were added to the library. The processing of all these books kept the cataloguer busy throughout the year. Much time was also spent in assisting the many students who now avail themselves of the library facilities.

The acquisition of the Arcor copying machine in November involved a great deal of extra work for the library; Mrs. McDonald spent much of the first three or four months after its installation instructing people in its use and keeping the accounts. With the transfer of responsibility for the machine Mrs. McDonald has been able to return to normal library work.

Miss Tuckwell having decided that she wished to return to archaeological work resigned in the summer after two years' valuable service. She was replaced at the end of July by Dr. Harriet Martin.

During the vacation Miss Bell toured Norway and visited ship museums and libraries there. Mrs. McDonald worked on Mr. Sheldon's excavation at Highgate and Miss Tuckwell joined excavations in Germany and Orkney.

The following is a summary of the additions made during the year:

Books	605	*Pamphlets*	388
Purchased	370	Purchased	103
Presented	133	Presented	213
Exchanged	102	Exchanged	72
Periodicals	561	*Volumes bound*	237

Volumes lent totalled 5,729, the highest month being February (753) and the lowest August (170). Forty-three volumes were borrowed from outside libraries and 75 lent.

The following have presented books, periodicals and pamphlets:

Dr. P. B. Adamson; Akademia Nauk, S.S.S.R.; A. V. Akeroyd; Dr. J. Alexander; T. Allison; A. J. Arkell; T. Batchelor; C. Belchior; H. Bell; Cmdr. A. Bax; Bibliotheque Scientifique de l'Universitet d'Etat de Tirana; Mr. R. Bloch; P. Bosch-Gimpera; Dr. W. Bray; Lady Briscoe; British Archaeological Association; British School in Ankara; D. R. Brothwell; N. Buchlerova; Cahiers d'Archéologie Subaquatique; California University Archaeological Research Faculty; P. Calmeyer; J. B. Campbell; University of Canterbury; L. Castigliart; City Literary Institute; R. J. Clarke; A. T. Clason; P. A. Clayton; Editor, Colchester Group; Dr. Cornwall; Secretary, Council for British Archaeology; Council for Nautical Archaeology; Dr. J. D. Cowen; A. Croome; J. E. Curtis; D. H. D'Arcy; A. G. Davies; J. E. Dayton; Department of Geography, University of Dundee; R. M. Derricant; Professor Dimbleby; J. Ducat; Dr. E. C. L. During Caspers; Editor of 'Endeavour'; Dr. G. Eogan; Professor J. D. Evans; P. Fett; Finland Research Seminar; Dr. I. C. Glover; Professor W. F. Grimes; Dr. A. R. Hands; A. Henderson; Historical Museum of America; H. Hodges; Dr. F. R. Hodson; V. Hollander; O. Holm; A. Horder; Human Environment Department; Institut für Vor- und Frühgeschichte, Bonn; Institute of Latin American Studies; C. E. Jeel; E. M. Jordan; L. Keen; Dr. K. M. Kenyon; W. Y. Kim; A. Kossé; Kragujevae Museum; A. D. Lacaille; Professor Lang; A. Latham: Director, Leicester Museum and Art Gallery; Librart; University of Liverpool; F. McDonald; E. McNamara; J. Mercer; Director, Museum of Art and Archaeology, Columbia, Missouri; Director, Museums Services; Muzej Grada Zenice, Yugoslavia; Dr. J. G. Nandris; Nakladetelstoi Czchesloenské Akademie Vád; National Maritime Museum; National Museum of Wales, Cardiff; National Museum

(Nat. Hist.), Hungary, Archaeological Library; Dr. M. H. Newcomer; University of Nottingham; Dr. K. P. Oakley; L. Pericot; D. Philips; A. P. Phillips; Dr. K. Prag; P. L. Prematillike; R. Reece; Dr. B. Rothenberg; The Royal Society; Dr. Sardinas; C. Schaeffer; K. Schmitt-Kerte; A. Sh. Shahbarzi; Dr. T. C. Sharma; H. Sheldon; J. M. Sheldon; Dr. P. Singh; Society of Antiquaries; H. Stewart; Professor T. Sulimirski; G. C. Talbot; J. du Plat Tayler; Tree Ring Laboratory, Tuscon, Arizona; University of Utrecht; L. Vagnetti; Dr. Waechter; J. Waterer; Director West Midland Studies; A. C. Western; L. Willis; G. R. H. Wright; Editor, Watford and South West Hertfordshire Archaeological Society; A. Young.